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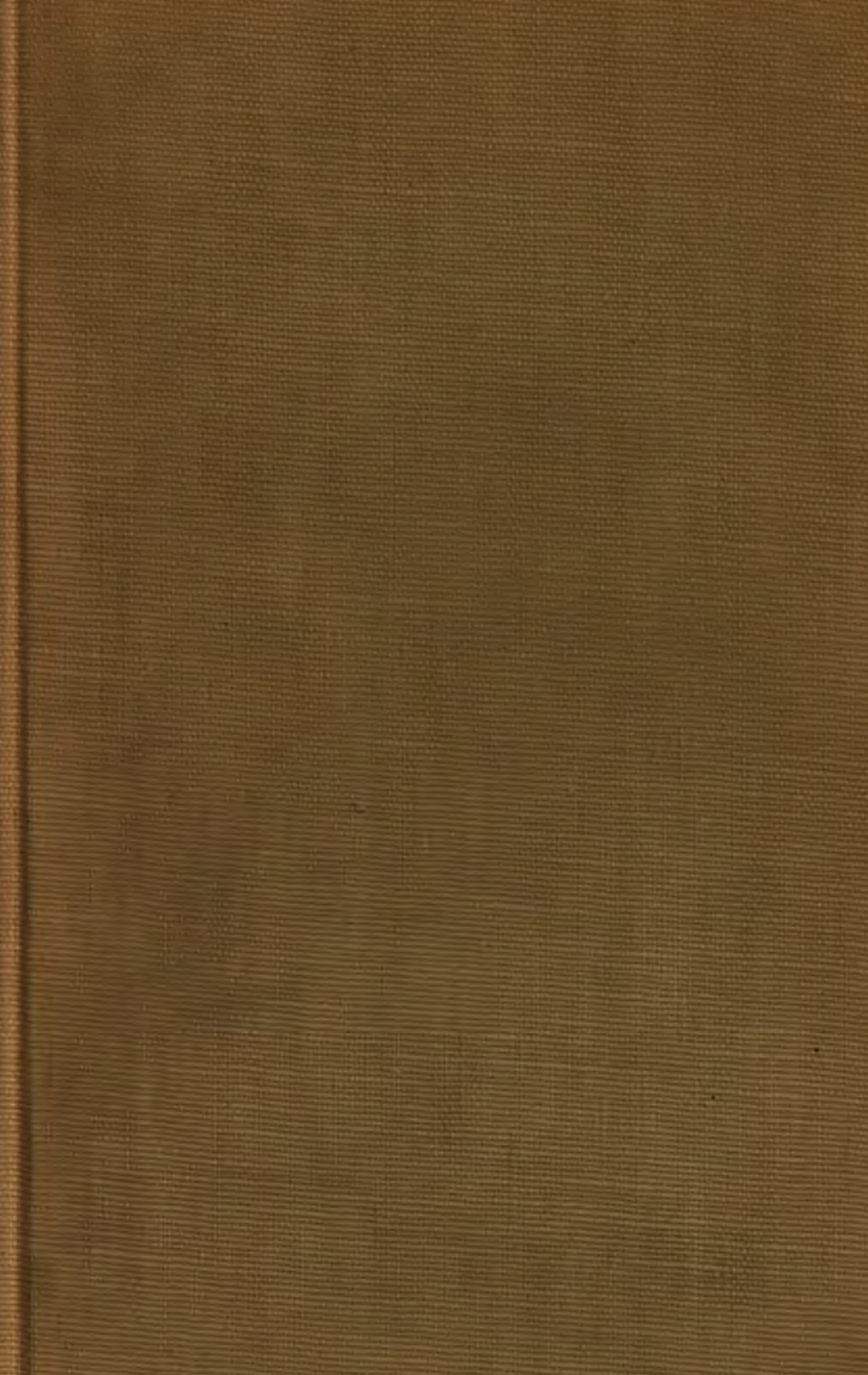
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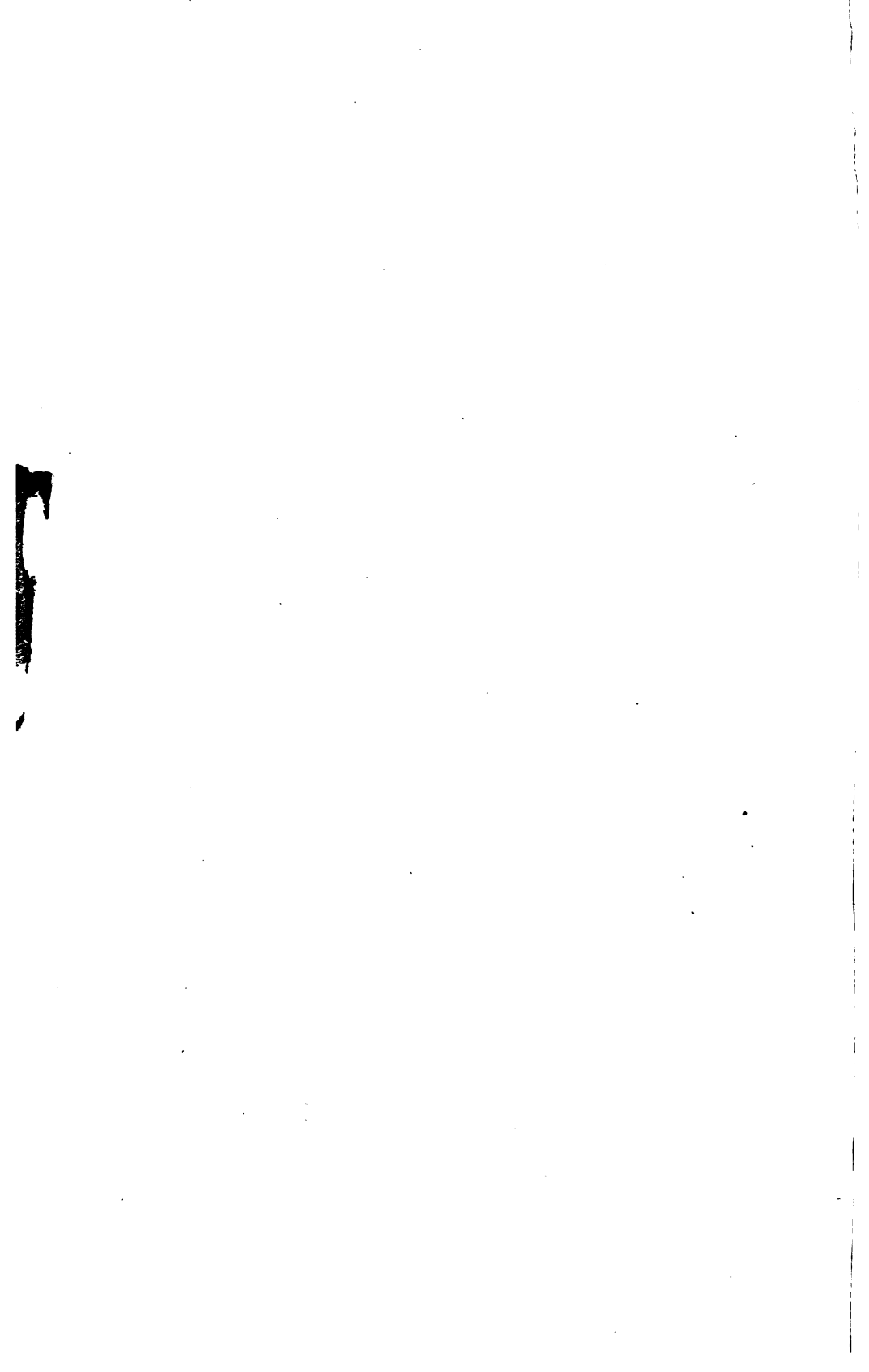


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New York State Museum Bulletin

Entered as second-class matter November 27, 1915, at the Post Office at Albany, New York,
under the act of August 24, 1912

Published monthly by The University of the State of New York

No. 199

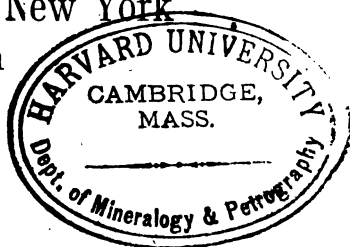
ALBANY, N. Y.

JULY 1, 1917

The University of the State of New York

New York State Museum

JOHN M. CLARKE, DIRECTOR



THE ADIRONDACK GRAPHITE DEPOSITS

By HAROLD L. ALLING

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1918

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The University of the State of New York
New York State Museum April 29, 1918

Dr Thomas E. Finegan
Acting President of the University

DEAR SIR: I transmit to you herewith for immediate publication as a bulletin of the State Museum a report on the Adirondack Graphite Deposits. The matter contained in this report is of exigent importance as it relates to the intensive development of a war mineral of the first moment. I therefore urge that its publication be expedited.

Yours sincerely
JOHN M. CLARKE
Director

THE UNIVERSITY OF THE STATE OF NEW YORK
OFFICE OF THE PRESIDENT

Approved for publication this 14th day of June 1918

A handwritten signature in dark ink, reading "Thos. E. Finegan", with a horizontal line drawn underneath the name.

Acting President of the University

Min. Kalu. Goss. plate

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The University of the State of New York New York State Museum

JOHN M. CLARKE, Director

THE ADIRONDACK GRAPHITE DEPOSITS

By HAROLD L. ALLING

INTRODUCTION

The world's chief supply of high-grade graphite comes from the island of Ceylon where it has been mined for nearly a century in a most primitive way but at low cost. In 1916 a little more than 70 per cent of the crude crystalline graphite used in this country came from Ceylon. Graphite is also mined extensively in Bohemia, Bavaria and Mexico, the last-named country being noted for the amorphous grade applicable to pencil manufacture. Madagascar has lately come into prominence as a source of the crystalline article and promises to vie with Ceylon in the quantity of exports, which already amounts to over one-half the total credited to that island.

The graphite-mining industry in the United States has been a slow development; only recently has it shown signs of a growth which may at last win for it a place of importance in the world's trade. The industry was established here as far back as the middle of the last century, for it has been carried on in the Adirondack region for more than sixty years. Yet the total output of crystalline graphite in 1916, according to the records of the United States Geological Survey, was only a little over 5000 tons, or less than 15 per cent of the indicated supply available for consumption. Of the total, New York State contributed about one-fourth, ranking second to Alabama in size of output, with Pennsylvania, California and Montana contributing smaller amounts. An incentive to the expansion of the domestic industry has been given recently by the curtailment of supplies from abroad and a consequent rise in prices paid for the native product. A continuance of these conditions may be anticipated for some time at least so that there is opportunity for

a very substantial increase in the development of our resources, in which the local industry should participate as fully as possible.

The present bulletin embodies the results of a survey of the Adirondack graphite districts, made in the summer of 1917. It aims to give a comprehensive estimate of the resources of the region so far brought to notice and to provide such information about the local geological conditions and other features which affect the outcome of mining and concentration of the graphite as may be useful in forwarding the future progress of the industry. In view of the current conditions, the publication of a report upon the Adirondack deposits which have so long occupied a prominent place in the industry of our country, may be held to be timely.

The writer would like to acknowledge his indebtedness to the many who have shown interest in the work or have assisted him in other ways. To Prof. George H. Chadwick he stands under especial obligations. The topographic maps of the graphite districts are in a large measure his contribution and he has also given freely of advice and suggestion in the study of the complex problems of geology—a service that can scarcely be expressed or valued by this formal acknowledgment.

EARLY MINING DEVELOPMENTS

The first attempt to extract graphite or "black lead," as it is popularly called, from the Adirondack rocks in any commercial way was on Lead hill (Chilson hill of some authors) near Ticonderoga, Essex county, N. Y. Graphite had been known to exist in this locality for a long time. Emmons mentions it in 1842,¹ and Beck gives a brief account of the occurrence.² In the fifties the deposits were being exploited by a company that eventually became the American Graphite Company. The Joseph Dixon Crucible Company, now of Jersey City, N. J., the first enterprise to import and manufacture graphite products in this country, took over the American Graphite Company in the eighties and has since been engaged in mining at one or another of its properties on Lead hill, at the Lakeside locality, at Hague, and at Graphite in Warren county.

About the year 1902 the Adirondack deposits began to attract general attention, and in the following years many prospects were opened, companies organized and mills for treating the ores were

¹ Emmons, E., Nat. Hist. N. Y. Geology of the Second District, p. 420.

² Beck, Nat. Hist. N. Y. Mineralogy, pt 3, p. 96-97, 1842.

built. Among the enterprises that entered the field at this time was a company which attempted to mine the Towne property. This company, after a year, abandoned work and moved to a site near Overshot pond, operating as the Columbia Graphite Company. There it found more ore but soon worked out all the available supply. Then it moved again, having dismantled its mill, and took over the holdings of the Ticonderoga Graphite Company at Rock pond. Much activity prevailed here for a time, but the property was soon leased to Pettinos Brothers of Bethlehem, Pa., who worked it for only a short time as the ore was cut off by a fault.

Another attempt at mining was made at the Buck Mountain pond locality, which also was not permanently successful. The property was worked for a time by the Consolidated Graphite Company and at another time by the Amalgamated Graphite Company. A huge mill was prematurely constructed and exists today as a dismal ruin.

Many companies that had started operations during the boom period failed to weather the financial stress of 1907 and have not attempted operations since. Fortunes have been lost in vain attempts to win the shining flake from the rocks of the Adirondacks. The history of the industry has been characterized rather by the number of failures that have been recorded than by the few examples of success.

One of the conspicuously successful enterprises has been the American Graphite Company. This company began operations on Lead hill, sending the graphite for treatment to its finishing mill at Ticonderoga. The pockety character of the graphite in the locality led the company to seek a more regular source of supply and it secured control of deposits of graphitic quartz schist in the town of Hague, Warren county, and began experimentation in the mining and treatment of this type of material. At Graphite, 5 miles west of Lake George, the company has developed the most important mine in the State. It has worked the graphitic quartz schist in Warren county ever since and has mined an immense amount of it. It would appear that the company was the first to abandon the northern area with its pockety contact form of graphite for the bedded or blanket type found in the southeastern Adirondacks. The large flake of the spectacular limestone and contact types still attracts attention. When, however, the mining of this kind of ore was found to be unprofitable, in general, the interest shifted southward, and several very promising mines have been opened and are operating on graphitic schist.

THE USES OF GRAPHITE

Contrary to the popular conception, the manufacture of lead pencils requires but a comparatively small amount of graphite, only about 5 per cent of the total being such material. This form of graphite is the amorphous variety. Other uses to which this form of material is put include electrodes for electric furnaces, dry batteries, electrotyping, paints, inks and numerous other purposes. A considerable amount of natural amorphous graphite is now supplanted by artificial material manufactured from coal by the heat of the electric furnace.

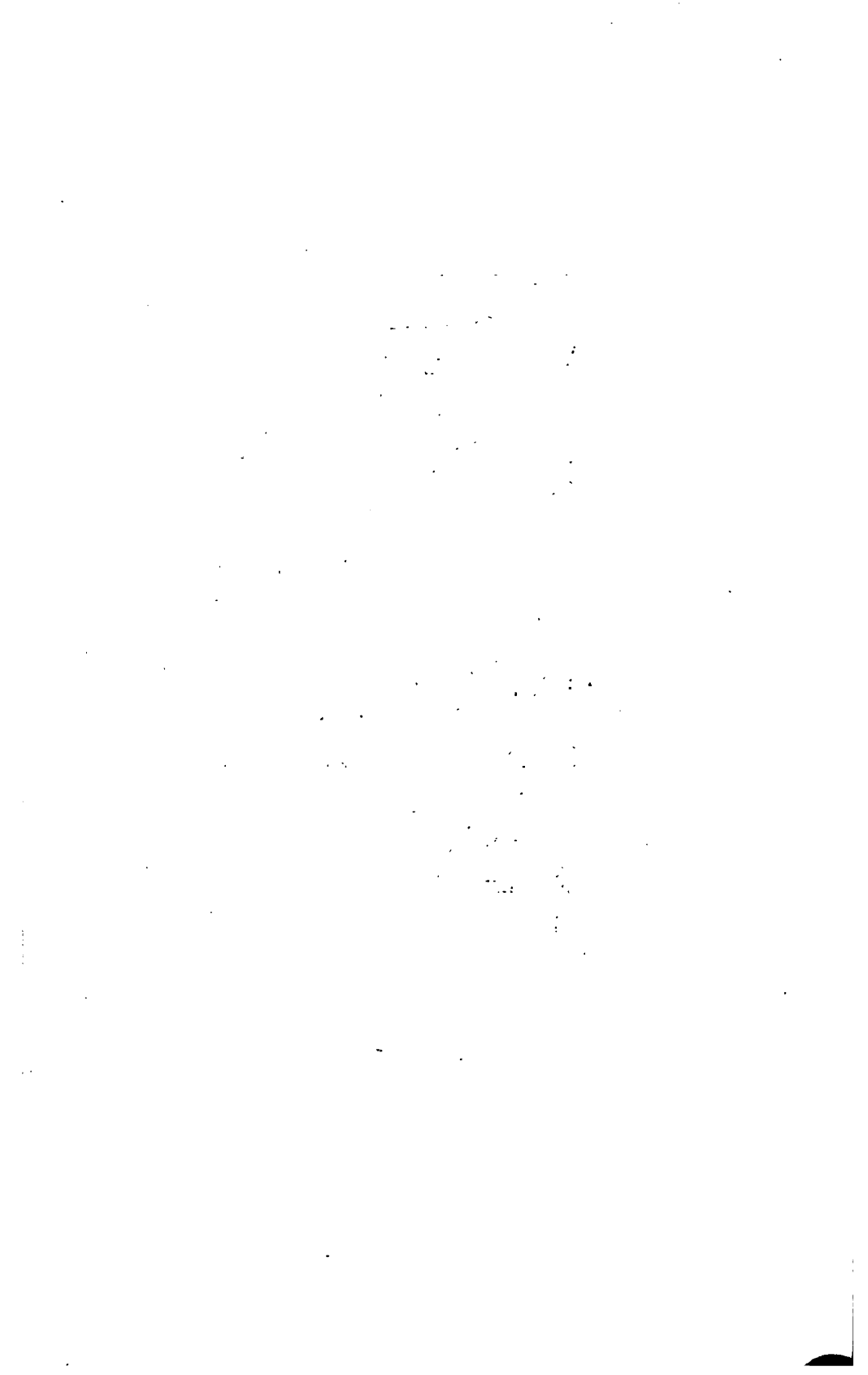
But we are more especially concerned with the crystalline or flake variety of graphite which nature alone seems able to produce. It is important to make a distinction between the two classes.

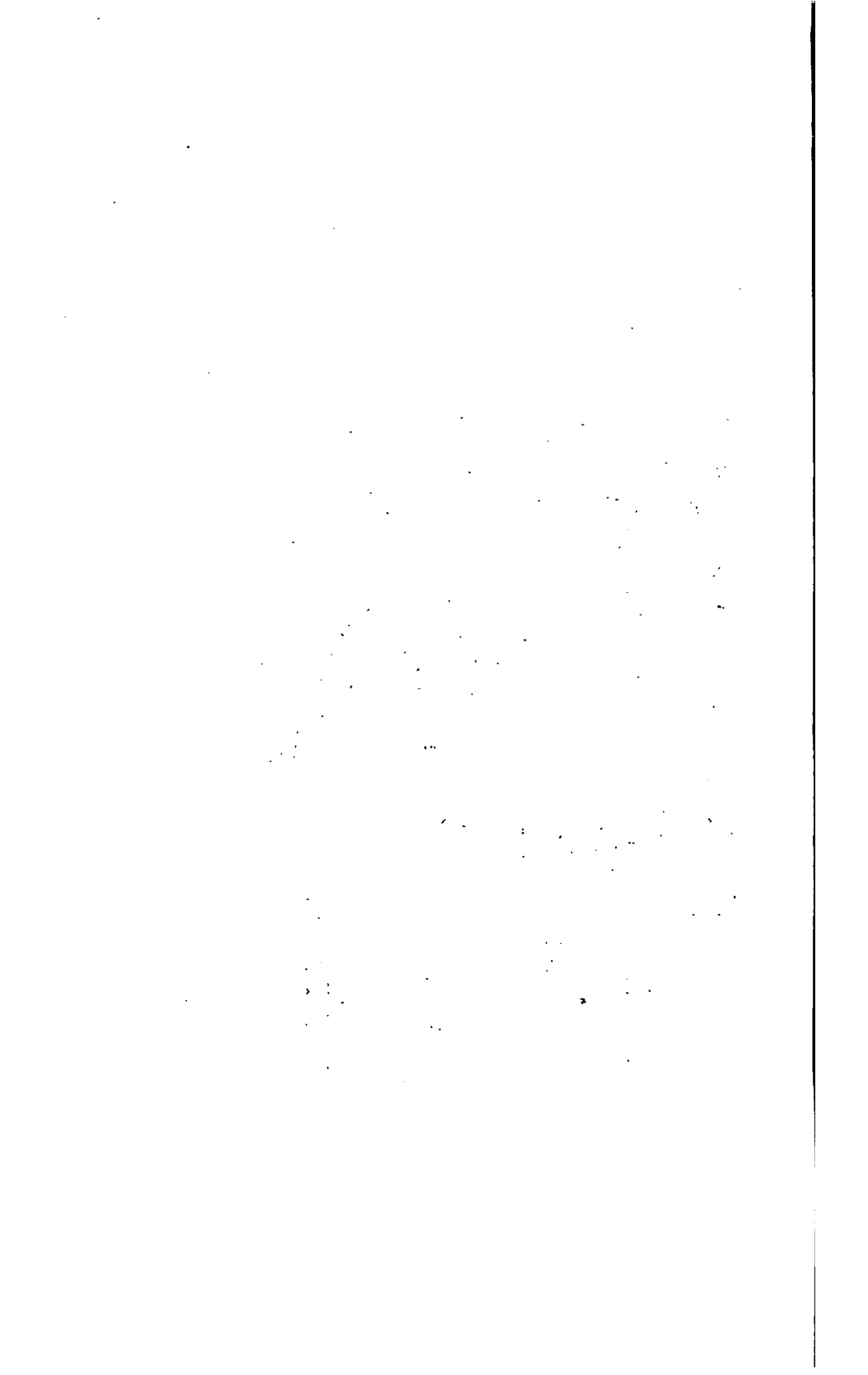
A great share of the flake graphite is manufactured into crucibles used in the production of crucible steels, brass and similar alloys. It has generally been held that Ceylon graphite alone was suitable, but the present shortage has resulted in the employment of domestic materials, at least in part mixed with foreign graphite and found to answer the purpose fairly well. The crucible manufacturers are today experiencing difficulty in maintaining their former quality as well as in meeting the market demands in quantity. This state of affairs is accounted for by the different characters possessed by the Ceylon and domestic materials and especially by the failure to secure a perfect substitute for the German clay used as binder. In 1916 the average crucible, it was said, was capable of withstanding only about half as many heats as the prewar articles. While this condition has been greatly improved, still the present crucibles do not equal the former in quality.

Stoppers used in closing poring holes in the huge steel ladles that receive the charges from furnaces, retorts and certain chemical wares are composed of graphite.

Second to refractory articles in consuming a large share of the supply is stove polish. The small-sized flakes (the intermediate grades) of the graphite mills are employed for that purpose. Graphite is being used more and more for lubrication, either in a dry condition as in textile mills where oil would soil the cloth, or added to lubricating oils and greases. In the latter form it is being extensively used in automobile lubrication.

The fine dust is used in metal paints and, when mixed with talc etc., is used as a facing to foundry molds.





DESCRIPTION OF THE GRAPHITE PROPERTIES

Although the chief purpose of this bulletin is to describe the commercially important deposits of graphite in Essex, Warren, Washington and Saratoga counties, an account of the unsuccessful mines is included, for many of them reveal features that furnish valuable aid in understanding the physical and geological conditions of graphite.

It has been found convenient to divide the eastern Adirondack graphite district into two areas — the northern, where the majority of the limestone and contact type of deposits occur, and the southern, which is characterized by the bedded or blanket form of ore body. (See the accompanying key map, figure 1).

The following prospects and mines occur in the northern area, listed from north to south.

The Gulf prospect, located in the township of Jay, Essex county, 4 miles south of Ausable Forks, is still undeveloped. No. 1 on the key map.

Split Rock prospect, now abandoned, is located in the township of Essex, Essex county, 8 miles northeast of Westport, just south of the Split Rock lighthouse. No. 2 on the map.

The Columbia Graphite Company's abandoned mine is situated in the township of Crown Point, Essex county, $2\frac{3}{4}$ miles north-northwest of Ironville. No. 25 on the map.

The Towne property lies in the township of Ticonderoga, Essex county, just south of the boundary between Crown Point and Ticonderoga and on the boundary between the Ticonderoga and Paradox Lake quadrangles. No. 3 on the map.

The Betsey Cook property is located in the township of Ticonderoga, 2 miles southeast of Ironville. Abandoned. No. 8 on the map.

A little prospect here called the Penfield pond property lies near the southern boundary of the township of Crown Point, near Penfield pond, and is not developed. No. 4 on the map.

The Buck Mountain Pond mine, now abandoned, is located in the township of Ticonderoga, between Buck mountain and Keeney mountain, as is shown on the Ticonderoga quadrangle. No. 6 on the map.

The Crown Point Graphite Company's mine and mill is likewise situated in the township of Ticonderoga $2\frac{1}{2}$ miles southwest of Ironville. The property is today abandoned. No. 5 on the map.

The Mason property (not developed) is located in the township of Ticonderoga three-eighths of a mile east of Echo lake (Worcester pond on the map). No. 7 on the map.

Lead Hill, located 3 miles northwest of Ticonderoga, in the township of the same name. This property is abandoned.

Contact type in the township of Wilmington, exact location not known, but probably somewhere on the shoulders of Wilmington mountain $2\frac{1}{2}$ miles west-northwest of Wilmington village.

The two following occurrences have been reported to but not visited by the writer. These are not indicated upon the key map.

Limestone type in the township of Newcomb, not far from village of Newcomb.

Contact or vein (?) type in the township of Minerva, just north of the town of Minerva (Schroon Lake sheet).

The next three prospects, although of the contact type, occur in the southern area:

A contact-limestone prospect, here referred to as the "Pottersville" prospect. This is located in the township of Chester, Warren county, $2\frac{1}{2}$ miles south of Pottersville. Not developed. No. 20 on the map.

A prospect in a natural cave, locally called Mammoth cave, located in the township of Warrensburg, Warren county, one-half of a mile north of Warrensburg. No. 26 on the map.

On Pardo point, on Lake George, is a vein deposit of graphite.

Mines in the southern area, all of the bedded or blanket type, although a few show in a minor way other types as well:

The Bly property, located in the township of Ticonderoga on the northern slopes of Bear Pond mountain, is still undeveloped. No. 10 on the map.

Rock Pond property. This abandoned mine is to the southeast of the Bly property on the shore of Rock pond. No. 11 on the map.

Dixon's American Graphite Company is situated at Graphite, 5 miles west of Lake George in the township of Hague, Warren county. No. 13 on the map.

The Faxon property adjoins the American Company's land on the west and southwest. This property is still undeveloped. It has recently been sold. It is understood that the property will be worked by the American Graphite Co. No. 14 on the map.

The Lakeside mine of the American Graphite Company is located at the town of Hague on the lake shore. Abandoned. No. 12 on the map.

International Graphite Company's abandoned mine is situated in the township of Chester, Warren county, $3\frac{1}{2}$ miles west-northwest of Pottersville. No. 15 on the map.

The Rowland Graphite mine, now inactive, is located in the town of Johnsbury, Warren county, about a mile south-southwest of the village of Johnsbury. No. 21 on the map.

The Adirondack Mining and Milling Company's abandoned mine and mill is on the west shore of South bay of Lake Champlain; township of Dresden, Washington county. No. 18 on the map.

Hooper Brothers' recently developed property lies in the township of Dresden, Washington county, about 4 miles due west of Whitehall. No. 17 on the map.

The Silver Leaf Graphite Company's workings are situated on the west side of South bay several miles north of the Adirondack Company's property. The mine has been abandoned. No. 16 on the map.

The Champlain Graphite Company. This property, likewise in the South Bay districts, is near the southern end of South Bay and has not been operated for ten years. No. 19 on the map.

The Sacandaga Graphite Company's property is located in the township of Day, Saratoga county, $1\frac{1}{4}$ miles due west of Conklingville. The mine is today abandoned. No. 22 on the map.

Graphite Products Corporation (formerly the Saratoga Graphite Company). This property now in operation is situated 1 mile southwest of King's Station, 4 miles north of Saratoga Springs in the township of Wilton, Saratoga county. No. 3 on the map.

The Flake Graphite Company (formerly the Empire Graphite Company). This mining district is located in the township of Greenfield, Saratoga county, $2\frac{1}{4}$ miles west of Porter Corners. No. 24 on the map. Probably will be in operation in 1918.

Several prospects reported to but not visited by the writer are as follows:

A limestone-contact deposit on the Welch farm, 3 miles southwest of Mineville.

A deposit 3 miles east of Hulett's Landing, Lake George.

Chamberlain & Company, 3 miles southwest of Canton, St Lawrence county.

M. W. Spalding, 4 miles southwest of Canton.

C. T. Holbrook, $1\frac{1}{2}$ miles southwest of Pyrites, St Lawrence county.

Macomb Graphite Company—Popes Mills Graphite Company, $1\frac{1}{2}$ miles southwest of Pope's Mills, St Lawrence county.

A deposit on the Indian River, 3 miles from Rossie, St Lawrence county.

Of the complete list, twenty-four of these properties were personally visited during the field season of 1917. The salient features of each will be discussed in the following pages.

THE GRAPHITE DEPOSITS OF THE NORTHERN AREA

While an attempt is made to avoid technical terms, certain concepts are necessary for a comprehensive grasp of the conditions found in the northern area.

Two general groups of rocks are involved: the first, a great series of sedimentary rocks originally bedded limestones, sandstones and shales that have been altered by earth forces to crystalline limestones, schists and gneisses. The second group comprises igneous rocks, among which granite is especially prominent. Igneous rocks are later in age and have invaded the sedimentary series from below. Where the hot fluid mass, saturated with various gases, came in contact with the sediments, especially if they were limestones, and the proper conditions obtained, graphite was developed by complex chemical and physical reactions within the zone of contact. The deposits of the northern area have, in large part, been formed by the process thus briefly outlined. The general subject of origin of the graphite deposits is treated fully on page 141.

The Buck Mountain Pond Property

Located in the township of Ticonderoga, Essex county, within the limits of the Ticonderoga topographic map of the United States Geological Survey, between Buck mountain and Keeney mountain,¹ near the shore of Buck Mountain pond.

The history of the various companies which have attempted to develop this deposit is extremely complicated but apparently the company which operated at one time was known as the Consolidated Graphite Company and at another the Amalgamated Graphite Company.²

The extent of the property is said to be a tract of 84 acres³ on the

¹ The local name of the latter is different from that given on the map.

² The Amalgamated Company included the Rowland Graphite Company near Johnsburg.

³ Information supplied by Mr Charles T. Rowland of the Rowland Graphite Company.

south side of Buck mountain about 7 miles by road northwest of Ticonderoga, and a like distance southwest of Crown Point at about 1100 feet elevation.

The mine openings lie directly west of the pond where the main bed of the graphite-bearing rock outcrops on the northern slope of a small knoll a hundred feet high, several hundred feet from the pond. These openings occur directly behind the mill and extend west along the outcrop for 230 feet. Then after passing an interval of 720 feet to the west a second cut extends about 200 feet. In neither case has the excavation extended beyond 40 feet in depth. The bed of graphitic material can be followed along the strike for 1000 feet or more.

The eastern pits. The ore consists of two distinct rocks: a soft crumbly limestone carrying fairly large flake graphite, and the footwall, a dense green rock¹ produced by the action of the neighboring granite upon the limestone. The rocks here strike north 40° west (magnetic)² and dip from 25° to 30° southwest into the hill.

In the main drift-opening a crush zone occurs indicating a minor fault that cuts off the soft limestone bringing in a hard, unweathered variety. The ore contains considerable mica (phlogopite).

The western pits. Here the dip is considerably greater, being from 50° to 60°. Professor Crosby suggested the possibility of a fault being located somewhere in the concealed portion of the interval. The writer offers below another interpretation.

The summit prospects pits. On the hillside above the western cut are several prospect openings displaying the contact type of ore. This, although of spectacular appearance, is not of commercial importance.

The mill equipment. The mill is situated near the pond, where a plentiful supply of water for the boilers etc., was secured by pumping. The mill was amply large but is now in a ruined condition. The equipment consisted of crushers, rolls, buddles, tube dryers and blotters which are today of no value.

Geology and structure. The ore is chiefly limestone which has been invaded by a coarse variety of granite, known to geologists as pegmatite. This is of later age than the limestone and when in hot fluid condition profoundly affected the limestone, producing the green contact rock mentioned above. Graphite has been developed in this rock by chemical changes taking place during the

¹ Professor Crosby, in a report upon this property, interpreted this rock as quartzite.

² All compass readings are given uncorrected for the convenience of the miners. The correction in 1917 was about 13° west of north.

injection and solidification of the granite-pegmatite. The granite, the parent of the pegmatites, lies to the north, forming Buck mountain.

Lying on top of the limestone is a black and white rock of sedimentary origin, belonging to the same series as the limestone. This is the "para-amphibolite," a hornblende schist.

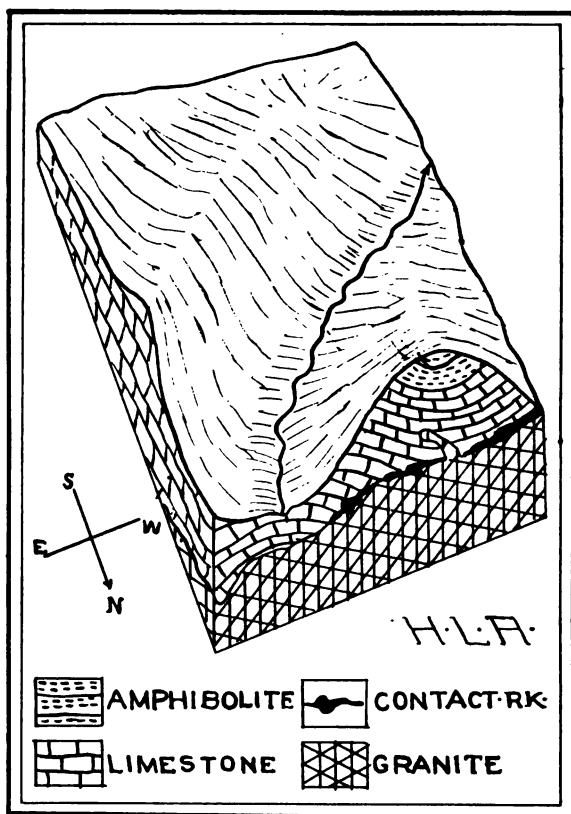


Fig. 2. Block diagram of the region at Buck Mountain pond, showing that the knoll is an anticline while the valley through which the outlet of the pond flows is a syncline. The old sedimentary series have been invaded from below by a granite. There is really more pegmatite than is actually shown. The end of the block toward the reader is an east and west section. H. L. Alling, 1917.

The knoll is composed of the sediments in the form of a trough, a syncline, while the valley to the east through which the outlet of the pond flows (at one point through a natural bridge) exhibits the opposite or arched structure — an anticline. Both the syncline and

the anticline are pitching southward, as can be seen from figure 2. The mine openings to the west are on the western side of the syncline and thus the dip is greater than is the case in the eastern group of pits; hence the reason to question the presence of the fault suggested by Professor Crosby.

Future of the property. Although specimens can be gathered that show a good display of graphite, the deposit, like most of them in the northern area, is of the limestone and contact type which experience has shown to be rarely of sufficient regularity to have commercial importance.

The writer is indebted to Mr D. G. McGrew and Mr Charles Rowland for information about the Buck mountain locality.

The Penfield Pond Prospect

Located near the southern boundary of the township of Crown Point, one-half of a mile west of Penfield pond, very close to the 80° angle in the boundaries between Crown Point and Ticonderoga.

It is a small limestone deposit of rather striking characteristics but of no commercial importance. Specimens of white, grading to pink and red, limestone carrying large flakes of graphite (one-fourth of an inch in diameter) may be obtained. The Crown Point Graphite Company first opened a deposit near Penfield pond, but whether or not this is the locality is not known.

The Crown Point Graphite Company

Location. This recently abandoned property is situated in the township of Ticonderoga 2½ miles southwest of Ironville, one-fourth of a mile south of the road which runs west past Eagle lake (Lake Chilson on the map), and 7½ miles southwest of Crown Point Center and 10 miles from Ticonderoga. It lies within the Paradox Lake quadrangle. The mine, located on the northern slope of a low ridge overlooking a swamp, was opened about 1907 and has lain idle since 1910.

Workings. The workings consist of four inclined shafts nearly in line (three abandoned and one recently worked). The dip of the rocks and hence of the shafts is 55°–60° southward. The main shaft is reported to be 72 feet deep “from which the miners have drifted eastward along the ore bed, removing a considerable amount of ore by stopping and finally reaching the surface again about 150 feet east-northeast of the shaft.”¹

¹ Bastin, E. S., Mineral Resources. U. S. G. S., 1908, 2:729.

There are several surface pits and a trench to the west of the mine.

The mill stands on the steep hillside facing north, so that gravity methods of ore handling could be employed. The top floor carries the hoisting engine as well as the ore bin, into which the ore was directly raised from the shaft. On the floor below are two rows of crushers which feed into burrstone grinders, and the boilers for the single tube-dryer. On the lowest floor are the main boilers, driving engines, mine pumps and packing room. The difficulty in securing abundant water forced the company to resort to the dry method of concentration. The details of this method are not available as the writer was informed that the process was a secret one. The mill concentrates were hauled to Crown Point Center and there refined in a finishing mill. The fuel used was coal hauled from Crown Point station. The following grades were prepared:

Mill concentrates: no. 1, no. 2, no. 3.

Finishing mill products: flake — no. 1, no. 2, no. 3; dust — no. 1, no. 2.

A sample of concentrate was secured and the following measurements were made upon the size of the graphite flakes. These were secured by means of a microscope especially arranged for the work.

The average diameter is based on ten measurements. It is not known what grade this sample represents.

Average diameter.....	91 x .65 mm
Maximum diameter.....	1.43 "
Minimum diameter.....	.39 "

The mill is said to have had a capacity of 30 to 50 tons a day.¹

Geology. The geology is very similar to that at the Columbia Graphite property (see below). A representative section beginning on the north side of the road and running south would be as follows:

- 1 Pink granite, cut by frequent stringers and dikes of pegmatite and occasionally holding inclusions of the sedimentary rocks.
- 2 The swamp, referred to above, probably is a limestone valley, with beds of uncertain thickness, not necessarily underlying the full width of the depression. A small patch of limestone was found near the base of the hill.

¹ Bastin, E. S., Mineral Resources. U. S. G. S., 1914. 2:208.

- 3 Limestone succeeded by a biotitic schist.
- 4 Amphibolite.
- 5 The limestone ore, varying greatly in thickness, as limestone is easily molded and stretched by dynamic disturbances.
- 6 A thick mass of pegmatite.
- 7 More granite which continues to the shore of Eagle lake. The granite has absorbed considerable amounts of the sedimentary rocks and is cut by frequent pegmatites.

All the rocks dip at an average angle of 55° to the south.

The ore. The ore is nearly pure limestone, in places charged with dark minerals (augite), the workable portion being from 3 to 7 feet in width. It can be traced along the strike (north 65° to 70° east) for a distance of a thousand feet. There is a second bed 375 feet south of the main bed that can not be followed for so great a distance.

Most of the graphite flake "ranges from 0.9 to 3.0 millimeters in length and from 0.15 to 0.3 millimeter in thickness. . . . A composite sample of the ore selected . . . so as to represent approximately the run of the mine was analyzed in the laboratory of the United States Geological Survey and showed 2.97 per cent of graphitic carbon." ¹

In places the pegmatite comes in direct contact with the limestone without affecting it in any appreciable way, and again there is a development of large feldspar crystals set in a groundmass of finer grains. A "porphyry" of this type is shown near a dam not far from the main shaft.

"The even distribution of the graphite through the crystalline limestone renders it probable that the carbon formed an original constituent of the limestone. Its conversion to the graphite state, the recrystallization of the limestone, and the development in it of the mineral pyroxene are the result of metamorphism, possibly in part dynamic but due to some extent to the contact effects of the neighboring masses of granite." ²

The term "metamorphism," especially that denoted as dynamic, refers to the changes taking place under the action of heat and pressure set up by stresses during mountain-making periods.

Future prospects. The future of the Crown Point graphite property is extremely doubtful. The limestone ore is uncertain in distribution, and the lack of mill water, the high dip, the necessity

¹ Bastin, E. S., Mineral Resources, U. S. G. S., 1908, 2:728.

² Loc. cit., p. 729.

for pumping and the long haulage are all against the successful operation of the deposit. The mill is in fairly good condition except that the machinery for final concentration has been removed.

The Betsy Cook Property

Located in the township of Ticonderoga 2 miles southeast of Ironville within the Paradox Lake quadrangle, at a fork in the road from Ironville to Echo lake (Worcester pond on the map).

The prospect holes consist of a long chain of shallow pits running northwesterly in a curved line. The southeast end is marked by a short drift, opened from a pit 8 feet wide, located behind an abandoned house, in a pyroxene-scapolite contact rock zone where a member of the sedimentary series has been affected by contact with a white granite. The sedimentary rocks here strike north 25° west, but the direction changes rapidly to north 60° west, eventually becoming north 80° west at the far end of the chain of pits. The bed is nearly on edge, dipping 83° north 46° east at the drift.

Geology. The graphite flakes, some of which are from one-fourth to three-eighths of an inch in diameter, occur in a dense green contact rock, usually badly weathered and stained brown due to the oxidation of the contained sulphides. The exact nature of the ore rock is complicated. It is chiefly composed of pyroxenes, hornblende, plagioclase feldspar, pyrite, biotite and titanite.

From a structural standpoint, we are probably dealing with an anticline that pitches very strongly northward cut to pieces by the granite which is usually bleached white on the line of contact.

The outlook for the property is certainly not bright. In the first place, the contact nature of the ore is against it; the presence of the biotite is another difficulty and the steep dip of the rocks is a third. It is fortunate for those interested that no mill was constructed.

The Towne Property

This abandoned property lies in the township of Ticonderoga, just south of the Crown Point-Ticonderoga boundary and on the border between the Ticonderoga and Paradox Lake quadrangles.

Pittsburgh capital became interested in the property and sunk a shaft in 1902, but gave up the enterprise the following year and moved to Overshot pond, operating under the name of the Columbia Graphite Company.

The workings consist of two openings about 6 rods apart. The eastern one is the shaft, about 108 feet deep, vertical and sunk

across the dip of the rocks. The second pit is 12 to 15 feet square and 6 feet deep, from which starts a slope down the dip (10° south, 30° west magnetic).

Geology. The conditions are very similar to those in the Betsy Cook locality. The rocks involved are the biotite-hornblende schists and associated members of the "Grenville" sedimentary series. The granite (of "Algonian" age) has affected the schists, producing contact rocks. In the vicinity of the shaft the ore consists of the usual pyroxene rock carrying large flake graphite and the usual pyrite. Specimens at the drift show a very different type of contact rock, composed to a large degree of feldspar (andesine-labradorite), partly altered to clay substances (sericite).

The granite is frequently coarse textured and approaches a pegmatitic phase at contact with the schist.

The high biotitic nature of this contact deposit and the limited amount of graphite force us to abandon hope that this will be of any importance in the future.

The Columbia Graphite Company

Location. The Columbia Graphite Company's property is situated in the township of Crown Point 1 mile east of Round pond and the same distance southeast of Overshot pond, $2\frac{3}{4}$ miles north-northwest of Ironville within the limits of the Paradox Lake quadrangle.

The workings. The workings consist of a series of deep, open cuts, all on the same line of strike, in green serpentized (verde antique) limestone close to pegmatite, usually having a foot-wall of fine-grained, sandy quartzite. Several shafts, inclined 62° south 68° west (magnetic) are today filled with water. The ore was hoisted and teamed to the mill a short distance away. Apparently no extensive operations had been carried on underground.

The mill has been dismantled and all the valuable material removed. Enough remains, however, supplemented by local information, for one to know that the wet method of concentration was used, the ore having been reduced to proper size by crushers, a 16-stamp battery, and burrstone grinders. Water was secured by pumping from a brook one-half of a mile away. The concentrates were sent to the finishing mill at Crown Point Center for final treatment.

Size of the Graphite Flakes in the Concentrates

	No. 1	No. 2	No. 3
Average diameter.....	.48 x .33 mm	.143 x .074 mm	.110 x .070 mm
Maximum diameter....	.90 mm	.310 mm	.150 mm
Minimum diameter.....	.20 mm	.015 mm	.030 mm

Geology. The geology in detail is most complicated, while the structure is comparatively simple. Starting to the north of the mine openings and proceeding southward, 15 feet of quartzite (approaching the vitreous type) is found dipping at a high angle under a sill-like mass of white granite of a similar thickness. A second bed of quartzite follows, heavily injected with granite, finally becoming sandy as it nears the limestone ore. The total thickness of the rocks here shown is about 70 feet. The ore is limestone carrying, besides the graphite, small amounts of dark green silicates that are today altered to serpentine, producing a verdé antique marble. Farther south the white granite occurs in a huge mass that eventually becomes pink, deepening into red.

Such a succession of beds could hardly be repeated in another parallel section because the granite and the pegmatites penetrate and cut to pieces the sedimentary layers in a most complicated way. In one of the pits, where a coarsely crystalline pegmatite is shown, beautiful crystals of brown tourmaline can be secured, as well as pyroxene, scapolite and other pegmatite-contact minerals.

Usually the line of contact between the pegmatite and the limestone is marked by the development of the characteristic green contact rocks, rich in pyroxene crystals and graphite flakes, the latter frequently three-eighths of an inch in diameter. This rock constituted a portion of the ore formerly utilized.

Structure. At the pits the rocks dip about 60° south 68° west (magnetic), while farther west the strike changes to north 10° east and the dip decreases to 42° east. Here we are probably dealing with a syncline which seems to pitch eastward. Thus the mine pits are located on the northern edge of a trough of sedimentary rocks highly injected and cut to pieces by pegmatite dikes.

Economic future. The mine was worked during 1903 and 1904 but the company moved to Rock Pond in 1905. It is not a difficult matter to comprehend the cause of the failure of the company.

The nature of the deposit is against profitable mining. The ore is very pockety and too variable to furnish any large supply. Mr D. G. McGrew, formerly connected with the company, and Mr Samuel Buck gave assistance and furnished information concerning this property.

The Mason Property

Location. This property lies in the township of Ticonderoga, three-eighths of a mile east of Echo lake on the shortest road from Ironville to Ticonderoga by way of Echo lake and Street road, the exact location being south of the road on a farm owned by Mr. Mason. Although only prospect work has been done, samples of the unusually large flake, some of which measured $1\frac{1}{2}$ inches in diameter, were sent to the American Graphite Company's mill at Ticonderoga but were found to be too large for treatment. The band of ore (the "vein" of the miners) strikes north 13° west (magnetic) and is said to be traceable for 20 to 30 rods, along which line nine openings have been made.

The size of the flake seems to grow smaller with depth from the surface. Mr Mason claims 12 per cent of graphite in the ore. Mica occurs on the southwest or hanging wall. The dip is very flat. The rocks shown here are limestone and pegmatite. One specimen of the latter carries black tourmaline. Like most of the deposits in limestone, the ore is localized in pockets and is exceedingly patchy, hence it is difficult, if not impossible, to estimate the quantity, but in all probability the supply is small.

The origin of the ore is clearly due to the action of the pegmatite upon the limestone, presenting the usual characteristics.

Lead Hill

Location. The property lies 3 miles northwest of Ticonderoga in the township of the same name and likewise within the Ticonderoga quadrangle, north of the "new" road to Eagle lake.

The extent of the property is considerable, comprising an area of several acres. There are numerous pits scattered over the southern and southeastern slopes of the hill, the important ones being shown on the accompanying map (figure 3).

History. As far as the writer has been able to ascertain, this property was the first to be exploited for graphite in the United States. It was well known that graphite occurred here in 1842, for Emmons says¹ that it "is well known at Ticonderoga where it forms

¹ Ebenezer Emmons, Nat. Hist. of N. Y., Geol. of the Second Dist. p. 420-21.

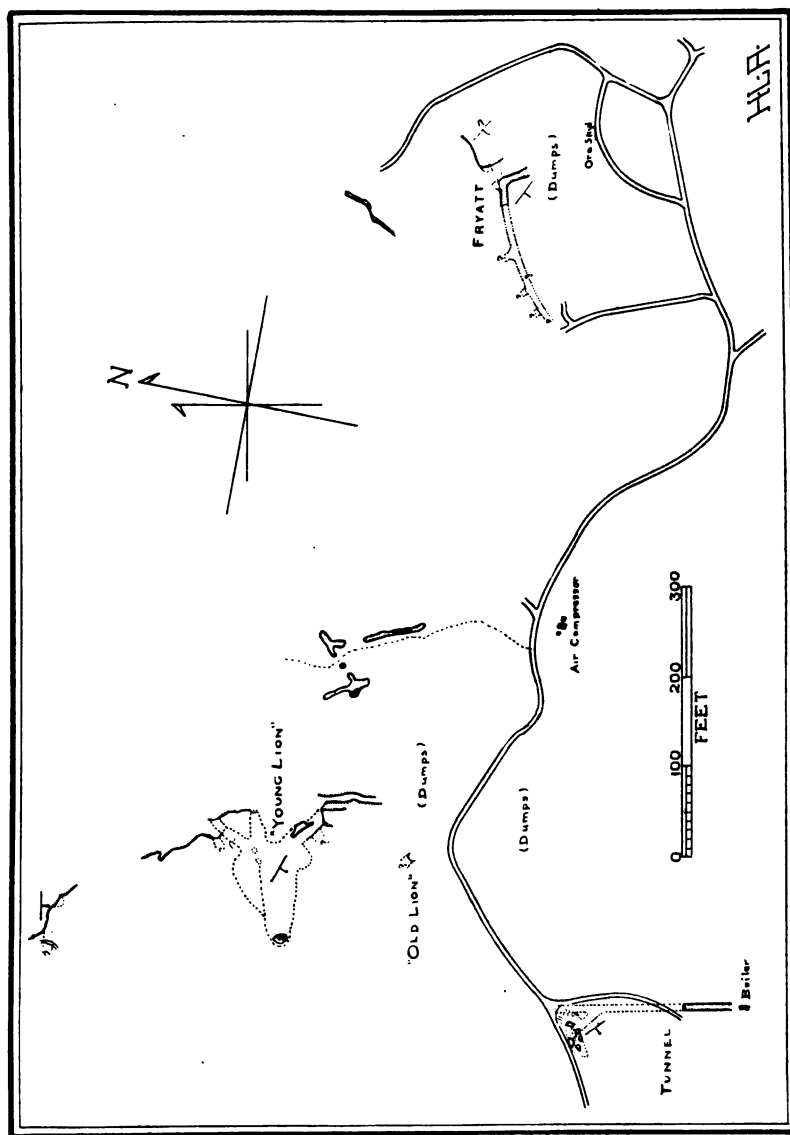


Fig. 3. Plane table map of the important workings on Lead Hill, near Ticonderoga, N. Y., showing the roads, open pits, underground workings and drifts. The workings in the southwest corner of the map are the so-called "Woodchuck" pits. Map by G. H. Chadwick and H. L. Alving, 1917.

a regular vein in gneiss." Beck¹ refers to it as occurring about 2½ miles from Ticonderoga at Upper Falls. "It is a vein of the purest foliated graphite several inches in width. The foliae often have a radiated arrangement, and are of considerable size. The gangue is calcareous spar, which often exhibits large and perfect cleavages. Granular graphite is also found associated with the above. This mine has not been much worked, but a considerable quantity of pure graphite is annually obtained from it, which is sold for a shilling a pound. It is thought that this is an extensive deposit."

It would appear that it was being worked by the American Graphite Company in the early fifties. The Joseph Dixon Crucible Company bought the American Graphite Company, and has exploited Lead hill, the Lakeside mine, and the great deposit at Graphite under that name.

In the early days, under the management of Mr William Hooper, the company was able to produce an exceedingly high-grade flake by using the ore-dressing machines that he developed. They made use of the wet method of concentration.

In the early days the interest taken in Lead hill was very great, but for reasons given below the American Graphite Company shifted its interest to the locality at Hague and that at Graphite. Since then the deposits on Lead hill have been worked only under small leases, among which was the Ticonderoga Graphite Company.

Today the locality is abandoned, although renewed attempts have been made to reopen some of the pits in recent years.

Workings. Of the various workings, six are sufficiently important to be treated separately. There are others that were reported to the writer, but the undergrowth and lumbering have rendered search very difficult. It is likely that some have escaped notice.

The "Woodchuck"² Workings. These are the first pits reached on approaching the property by the old wagon road. A group of three irregular shaft openings has been made along the line of contact between limestone and pegmatitic granite. Underground, various connecting passageways join them together. At a depth of some 40 feet they are tapped by a horizontal drift, which is a branch of the main one driven from the hillside to the south (see accompanying map, figure 4). The drifts were driven some twelve years ago, while the shaft openings were made much earlier. Dur-

¹ Beck, Nat. Hist. of N. Y., pt. 3, Mineralogy, 1842, p. 96-97.

² This is not the proper name, but conflicting opinions among the former workers necessitate the employment of this nickname.

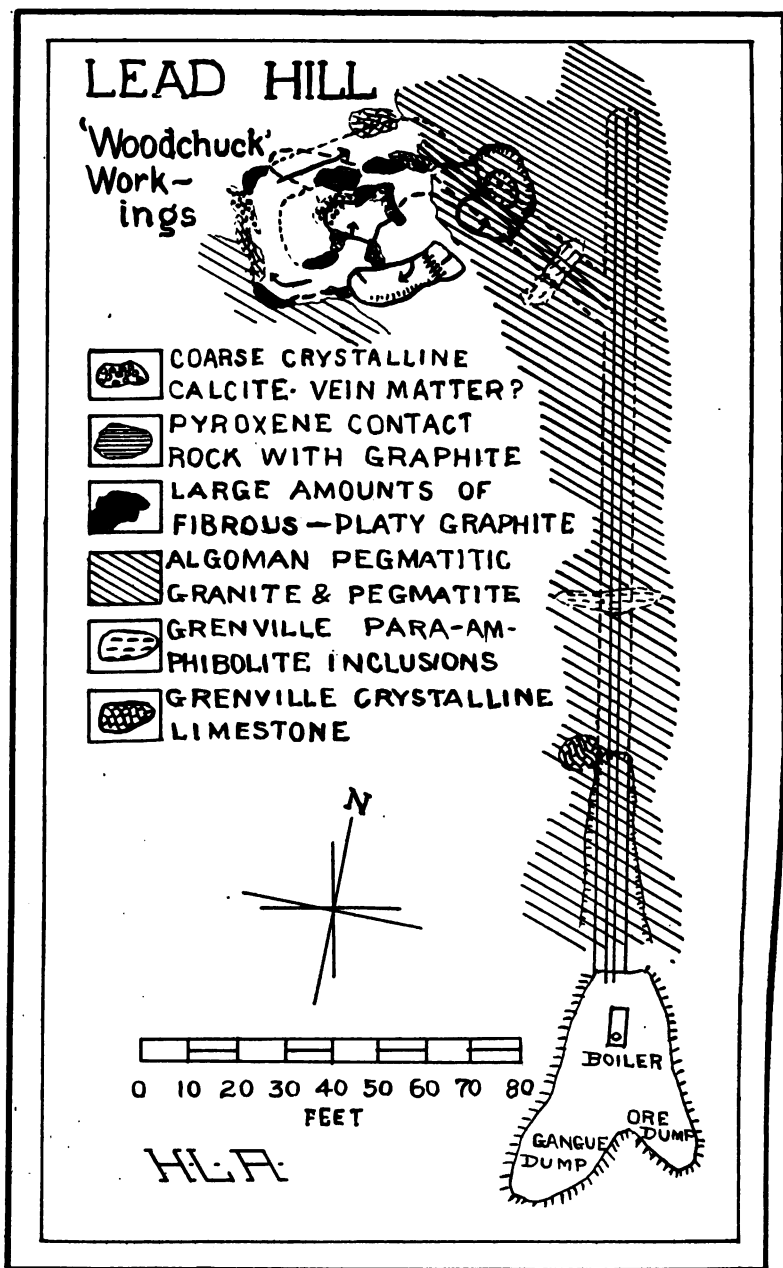


Fig. 4 Geologic reconnaissance map of the "Woodchuck" workings on Lead hill. G. H. Chadwick and H. L. Alling, 1917.

ing the last five years the main drift was extended farther with the hope of finding more ore, and at the same time for the purpose of tapping the bottom of a large slope pit (the Young Lion pit) farther up the hill to the north, but the attempt was eventually abandoned. The contact rock zone, which carries spectacular graphite, is likewise variable in thickness and in distribution. For the most part it is a white to green pyroxene rock with accessory scapolite. Frequently the pegmatite develops very coarse textures and shows feldspars 8 inches long; on the other hand, certain contact phases show large black-green crystals of pyroxene. Under a stringer or sheet of pegmatite is a mass of coarsely crystalline calcite, something like 3 feet in thickness. Between this and the capping igneous rock is a 3 inch layer of quartz, the under surface of which is coarsely crystalline showing the characteristic habit of the mineral. The edges of all the crystals are rounded, and very smooth as though corroded by solutions. This quartz, when examined under the microscope, appears to be vein matter. One of the hypotheses to account for the origin of this layer of calcite is that it represents a true fissure vein. The other theory is that the limestone has been recrystallized by the action of the pegmatite. In the Fryatt workings (described below) the contact is along sandy quartzite and there the prevailing rock is quartz, being possibly a recrystallized portion of the quartzite.

The drifts, especially the main one, run through barren pegmatitic granite which occasionally holds inclusions of sedimentary amphibolite, still maintaining the original relative positions with sharp outlines and without any graphitic development. Near the portal of the main drift lies a small mass of limestone overlain by a sheet of pegmatite, likewise without any graphite. At another point the pegmatite has penetrated the limestone, which still retains its crumpled and distorted foliation, by "lit-par-lit"¹ injection producing an injection gneiss. Still again the pegmatite becomes porphyritic with phenocrysts 2 inches long.

The Young Lion pit. This lies to the north of the "Woodchuck" pits a little to the east. It consists of a large underground chamber extending diagonally down the dip with an average slope of 22° and for 100 feet westward. It was once timbered but the pillars have long since rotted and large blocks have fallen from the roof, resulting in a lofty cave.

¹ French, "bed by bed." Applied to a structure composed of alternating bands composed of sedimentary and igneous rocks.

The same pegmatitic granite (largely an andesine rock) is shown here but the country rock is the sedimentary amphibolite, dipping 20° to 22° south 20° west (magnetic). The east wall is pegmatite and, as far as the section shown in the pit is concerned, can be regarded as a vertical plug which has sent dikes and stringers of its own material westward into the amphibolite, producing large flake graphite on contact. Much of the ore taken from the Young Lion pit is pure white pyroxene, in which flakes of graphite one-fourth of an inch in diameter are promiscuously distributed. The far end of the pit is filled with water. It is understood that the long drift at the "Woodchuck" workings was begun in an attempt to tap this to furnish drainage, but the enterprise was poorly planned inasmuch as they would have failed to make connections if the initial direction had been maintained. Along the line of contact with the main mass of pegmatite and the amphibolite the miners have removed a large amount of ore by stoping, reaching to the surface in several places.

The Old Lion tunnel. About half way between the "Woodchuck" and the "Young Lion" pits is a portal to a drift that is said to connect with the Young Lion pit.

The higher workings. Higher up and above the Young Lion pit are a series of workings, side wall pockets, trenches etc. They reveal examples of the same type of contact — the pegmatite upon the amphibolite.

The Fryatt workings. These are located a little to the east of the Young Lion pit, north of the old wood road, consisting of open pits verging on drift openings on two distinct levels. The upper series consist of two wall pockets, from one of which an inclined tunnel leads to the lower level to the west. The workings on the lower level comprise two wall pockets driven some 6 to 8 feet into the north wall. A drainage trench leads south. At the west end of the main pit a drift has been driven westward, rather near the surface, for in places this has fallen in.

The geology here presents a third species of contact deposit. Here the ore is the green augite-scapolite (the latter mineral is chiefly meionite¹) rock. Closely associated with the contact rock is a quartzose material that may be either recrystallized quartzite or true vein matter. It is analogous to the crystallized calcite in the

¹ Bastin, E. S., *Economic Geology*, 5:147-48.

"Woodchuck" holes. At the pits themselves it is not possible to determine what the country rock is, but 55 feet east from the wall pockets on the upper level an exposure of the sandy quartzite schist occurs that shows the relations. The pegmatite overlies the quartzite and has developed the pyroxene-scapolite rock on contact. The line of demarcation between the three rocks is exceedingly irregular, although it is an easy matter to see that the pyroxene-scapolite rock increases in thickness on leaving the quartzite exposure to the west. The north wall consists of alternate layers and masses of quartzose and contact rocks. The lenses or blocks of green rock are often "lit-par-lit" injected with pegmatite. They are furthermore frequently fringed with foliated graphite. Near the contact with the pegmatite, the more dense pyroxene rock is comparatively barren of graphite.

The sixth set of workings. These are found higher up and to the north of the Fryatt workings. They consist of a narrow trench showing the pegmatite in contact with a quartz-feldspar rock which appears to be of sedimentary origin.

Other workings. South of the old road, supposedly to the east of the "Woodchuck" drift, there is said to be another group of workings known as the "Old Indian" which the writer was unable to find.

Summary of the pits. Four different members of the sedimentary series of rocks can be seen on the hill. Under certain conditions the pegmatitic granite has developed graphite on contact with every one of them: in the "Woodchuck" with limestone; in the Old Lion, the Young Lion and the higher pits with amphibolite; in the Fryatt with sandy quartzite; and in the sixth set with quartz-feldspar gneiss.

The ore. In every case the ore sought and mined was a variety of contact rock. It is often a most beautiful rock making very attractive museum specimens. The flake is frequently as large as a dime. An analysis of the Lead hill graphite, as given by Cirkel¹ is as follows:

Carbon	Hydrogen	Ash
99.87%	0.11%	0.02%

¹ Cirkel, Fritz, Can. Geol. Surv. Dep't of Mines, Mines Br. "Graphite," 1907. Analysis by Luzi, Berl. Ber. 1891, 24, 4085.

Concentrates. The following measurements have been made upon concentrates from ores of Lead hill:

	"Arthur vein"	Pit unknown
Average diameter.....	.38 mm x	.38 mm x
Maximum diameter.....	.50 mm	.57 mm
Minimum diameter.....	.80 mm	1.10 mm
	.32 mm	.22 mm

Analyses of contact rock on Lead hill

MICROSCOPIC ANALYSIS				CHEMICAL ANALYSIS	
(Specimen 665 — Young Lion pit)				(Specimen collected by Bastin)	
APPROXIMATE COMPOSITION	Graphite.....		6.0	SiO ₂	47.91
	Augite.....		54.0	Al ₂ O ₃	6.32
	Scapolite.....		35.3	Fe ₂ O ₃	.33
	Titanite.....		1.5	FeO.....	3.11
	Tourmaline.....		1.4	MgO.....	11.86
	Pyrite.....		.7	CaO.....	22.88
	Quartz.....		.5	Na ₂ O.....	.40
	Zoisite.....		.6	K ₂ O.....	.46
	Total.....		100.0	H ₂ O—.....	.96
SIZE OF THE GRAPHITE FLAKES	LENGTH IN THIN SECTION	Ave.....	1.84 mm	H ₂ O+.....	.10
		Max.....	2.80 mm	TiO ₂	.44
		Min.....	1.50 mm	CO ₂	.95
	THICKNESS IN THIN SECTION	Ave.....	.095 mm	P ₂ O ₅	.25
		Max.....	.190 mm	S.....	.05
		Min.....	.030 mm	FeS ₂.....	.....
				C.....	4.00
				Total.....	100.10
				Less O.....	.02
				Total.....	100.08

The chemical analysis by George Steiger in the laboratories of the United States Geological Survey, U. S. G. S. Bul. 591, p. 40.

The quantitative microscopic analysis by the writer by the camera-lucida-polar planimeter method. These are approximate values by weight. See page 50 for a description of the methods employed in obtaining these results.

Its variable nature and its pockety distribution are factors leading to irregular supply, and precarious mining conditions. The supply is by no means exhausted but the writer feels confident that Lead hill can never regain the reputation that it held for so long in the early days of the graphite industry.

True fissure veins. Besides the contact type of graphite, the mineral occurs "in narrow veins from one to two inches wide, most of which are vertical and trend nearly north and south. They cut indiscriminately across the schists and pegmatitic granite, but in a number of cases apparently disappear when crystalline limestone is reached. In them graphite is usually the only mineral recognizable and forms aggregates of nearly parallel blades arranged about at right angles to the walls of the vein and closely resembling certain of the Ceylon occurrences. In most places the walls are sharp, and the pegmatitic granite shows no change of texture next to the vein. In a few places, however, the pegmatite becomes pyroxenic, finer grained, and somewhat graphitic next to the vein."¹

"Kemp describes the graphite deposits . . . as true fissure veins cutting the laminae of the gneissic walls at nearly right angles. The wall rock is a garnetiferous gneiss with an east and west strike, and the vein runs at the big mine 12° west with a dip of 55° west. The vein filling is evidently orthoclase (or microcline) with quartz and biotite and pockets of calcite. The mineral is also associated with tourmaline, apatite and sphene [titanite]."²

The deposit on Lead hill has been popularly referred to as a "vein" or as a "dike." While it is true that very small veins do occur, the important graphite rocks are *contact rocks, and not veins*. The former do not extend in any definite direction such as is implied by the word "vein" or "dike." This matter is brought to the attention of the reader with the hope that the past nomenclature, which is clearly erroneous, may be corrected.

Split Rock Prospect

This is in Essex county, in the township of Essex, 8 miles north-east of Westport, within the Willsboro quadrangle, 30 to 40 rods south of the Split Rock Light House.

Workings. These consist of (1) a prospect pit verging upon a vertical shaft about 20 rods from the shore at an elevation of 60 feet above Lake Champlain, and (2) an opening for a drift on the lake shore, east of the pit. It is believed that an attempt was made to sink a shaft, which the pit represents, to join the horizontal drift.

Geology. The northern and eastern shore of the point shows members of the sedimentary or Grenville series of rocks which include schists and garnet gneisses, associated with crumpled

¹ Bastin, E. S., Mineral Resources, U. S. G. S., 1908, 2: 730-31.

² Cirkel, Fritz, "Graphite," Can. Dep't of Mines, Mines Br. 1907, p. 56.

crystalline limestone dipping at a high angle into the lake. Several dikes of later age cut all the rocks in the vicinity. Near the light-house on the shore there are three dikes of great scientific interest.¹ The strike of the rocks varies greatly. The following measurements were obtained: N 19° E, N 30° E, N 35° E (magnetic), while the corresponding dips were 37° S, 69° E, 30° S, 60° E, and 45° S 55° E.

Away from the shore the Grenville rocks grade into syntectonic rocks because of the assimilation and soaking due to the igneous activity of the intruding batholithic dark green gabbro (Algomian in age). This shell of syntectonic rock² covers the gabbro so that the typical rock is not exposed until the shoulders of Split Rock mountain are reached.

We may regard the entire point as a section of Grenville strata which has been domed by an invading mass of gabbro. Numerous pegmatites (quartz-andesine rock) of the gabbro cut the overlying rocks.

The wall rock of the pit is a mixture of various contact rocks, including the usual green pyroxene rock with a high pyrite content. The latter carries microscopic traces of gelena (PbS) which is replacing the pyrite as beautiful intergrowths. The development of the graphite is limited to the immediate vicinity of the pit, which led the prospectors to think that they were dealing with a "vein." The occurrence of graphite on the lake shore also caused them to believe that they had found the continuance of the same ore body. The incorrect use of the term "vein" has been extremely unfortunate in practical mining, not only here but also in other sections of the graphite area.

After the miners had pushed their tunnel about 30 feet into the hill they encountered a diabase dike (augite-camptenite) 10 inches wide associated with a crush zone formed of brecciated fragments of itself indicating post diabase faulting. The dike strikes N 70° E with a dip of 45° N 20° W. Beyond the dike the rock is barren of

¹ Apparently a dike of diabase (microscopically an augite-camptenite) originally 6 to 7 feet wide, fractured and intruded by another dike of similar composition, but later in age. This was probably about 3 feet in width. Microscopically, it comes near to hornblende-camptenite. This latter dike is split and a third dike, 2 feet wide is intruded. This is the Bostonite. When Kemp and Marsters visited this locality in their study of the dikes of the Champlain region (U. S. G. S. Bul. 107) this "three story" dike was hidden by a boat-house, but this has subsequently been removed, exposing the dikes. It is hoped that this remarkable occurrence of three dikes cutting one another will be treated more fully elsewhere.

² Meaning a composite rock due to a mixing of two or more of distinct species.

graphite. The amount of displacement and the nature of the fault is unknown. Near the mouth of the drift-opening the rocks are highly folded and involved with the gabbro in a very complex manner.

In 1898 graphite veins were reported as occurring on Split Rock mountain.¹ It would seem as if these were not located at the spot where the above contact deposits occur. Kemp says that "at Split Rock . . . narrow veins or veinlets of graphite have been found crossing the gneisses, and filling fissures up to an inch in width. The graphite is in rather coarse leaves, and stands at an angle, somewhat less than a right angle, to the wall rock. Considerable vein quartz is mingled with it, and it is not so pure as one would infer at first sight. A large deposit of this sort would be the richest and most desirable of all, but veins have not yet been found crossing the gneisses in sufficient abundance to justify mining."²

It has been the opinion of graphite men and of the early geologists that graphite frequently occurs in veins. As has been said, some confusion resulted from the improper use of the term, which has been applied indiscriminately to graphite deposits of various origins. While it is true that fissure veins carrying graphite do occur, as is the case in the vicinity of Split Rock, they are insignificant and of no commercial value.

The Gulf Prospect

This property is in the township of Jay, Essex county, 4 miles south-southeast of Ausable Forks within the Ausable quadrangle or, more explicitly, to the east of the East branch of the Ausable river, a mile south of Ellis mountain, at the western entrance of a deep and narrow fault line valley known on the government map as the Gulf. Directly to the south runs a similar valley at right angles to the former, locally known as the South gulf.³ The prospect is surrounded by hills on three sides, while to the west the ground slopes gently to the river.

Prospects. No definite information could be obtained in regard to the dates of prospecting, but from the appearance of the small diggings it is judged that it was done many years ago and has not been renewed. Several small diggings were made on both sides of the road running through the South gulf as indicated upon the

¹ The Mineral Industry for 1898, p. 383.

² Kemp, J. F., U. S. G. S. Bul. 225, 1903, p. 512-13.

³ For the glacial geology of this region, especially the significant rôle played by these fault line valleys, see Bul. Geol. Soc. Am., 27:645-72, especially p. 658-60.

accompanying map. One of them is in the quartzite; the others are in amphibolitic limestone.

Geology. The range of rocks is rather complete. The sedimentary series is represented by two distinct strata of the quartzite and limestone, the latter of which in contact with igneous rocks has developed an amphibolite phase. The first rock found on approaching the property is a firm quartzite schist, usually graphitic, dipping 55° to 60° eastward, followed by an igneous rock that is very common in the center of the Adirondacks, known as anorthosite. Here it has been crushed and is somewhat "pulpy" in appearance. Then follows a pure limestone carrying a very small percentage of the usual silicates, but no graphite. Above occurs a quartz-feldspar (the feldspar is orthoclase) schist that likewise is graphite-free. Closely associated with the schist is a dense, hard; green quartzite. Cutting the sedimentary rocks are small dikes or bosses of a fine-grained variety of the augite-syenite. Especially in the vicinity of the diggings this rock has produced contact effects, including the development of large flake graphite. These flakes occur both in the limestone and in the quartzite.

The next rock is a fine-grained equigranular rock, nearly black in color and rich in garnets. This basic (femic) rock occurs as a dike 4 feet wide with a direction N 50° W (magnetic) near the western edge of the map. The writer has encountered several similar ones in the Adirondacks but has never seen them described. Under the microscope a specimen consists of augite, hornblende, basic labradorite and garnet. Mineralogically it might be classed as a gabbro but the texture is very different. This cuts all the above mentioned rocks in the vicinity. The last rock to be noted is diabase (augite-camptonite), two dikes of which were observed. All the dikes occur along the fault line of the gulf.

Ores. The graphitic rocks are clearly of two kinds: first, and most important, is the lower quartzite which carries medium to large-sized flakes, but no mica or clay substances. It splits readily but would be a hard rock to crush. The south road crosses several ledges of this quartzite, which dip at a high angle into the hills to the east. There appears to be a good supply of the mineral from what could be seen, although the glacial drift, which is exceedingly thick, obscures much of the surface.

The other type of ore has already been mentioned. It occurs as a contact effect where the small tongues of the augite-syenite cut the quartzite and limestone. The farmer who lives in the log cabin

indicated on the map informed the writer that he has repeatedly plowed up chunks of graphite as big as his fist. It is a fine composite of very small flake and amorphous material.

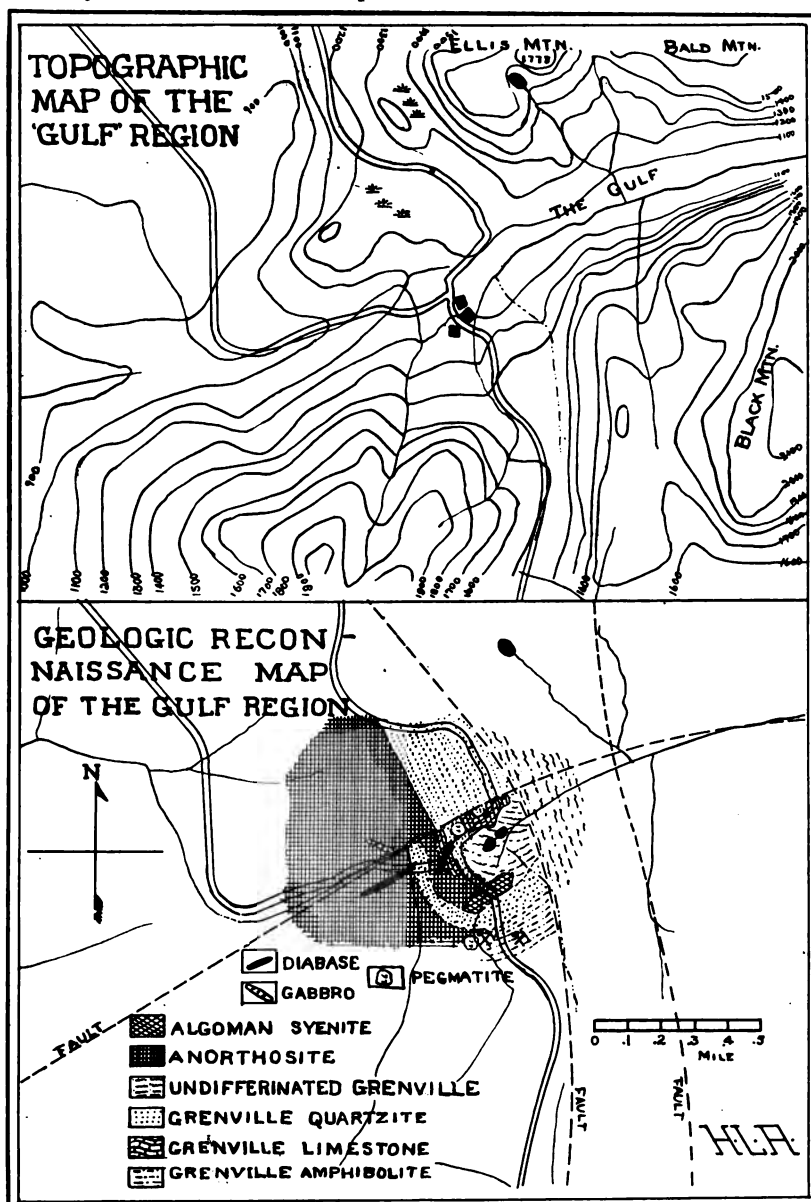


Fig. 5 Geologic and topographic reconnaissance map of the Gulf region, Ausable quadrangle. The topography taken from the Federal map; geology by H. L. Alling, 1915 and 1917.

Mining conditions. No active mining has been undertaken at the property, but the writer looked the situation over with such a prospect in mind. The north road is the one employed by the farmer and is passable even for a motor car. It is $3\frac{3}{4}$ miles by dirt road to the state road at Stickney Bridge, then 2 miles to Ausable Forks, the terminal of the Ausable branch of the Delaware and Hudson Railroad.

At the property there is not a sufficient supply of water for the wet process of concentration, nor is there water power. At Ausable Forks, however, there is probably sufficient water power for a finishing mill and in addition electric power is available.

Amount of ore. The quartzite ore is the only attractive material. It is impossible to say how much there is of it. The outcrop measures some 20 feet in width, while the extent along the strike is difficult to determine. It is possible that the Gulf and the South gulf faults delimit the amount of ore. The high angle of the dip is not favorable to mining. Considerable exploration will be necessary before anything more definite can be stated.

The Welch Prospect

This property is in the township of Moriah, Essex county, 3 miles southwest of Mineville, on the Welch farm, Newland¹ reports that "some prospect work has been done on a bed of graphitic limestone . . . which outcrops along the crest of a low hill and is accompanied by pyritous gneisses which are also more or less graphitic. In one pit a very rich band of limestone has been found, giving assays as high as 15 per cent graphite. The flakes are large and are built up of many laminae into comparatively thick plates. There is little mica in the rock, the accompanying minerals comprising pyroxene, serpentine, pyrite, tourmaline and quartz. The mining rights on the property are owned by the firm of Witherbee, Sherman & Company of Mineville."

It would appear from the above that this bed of limestone has been enriched by contact with some igneous rock, presumably pegmatite.

The Wilmington Prospect

This property is located in the township of Wilmington, Essex county, about $2\frac{1}{2}$ miles west-northwest of the town of Wilmington. It is situated at an elevation of about 2800 feet on the shoulder

¹ Newland, D. H., N. Y. State Mus. Bul. 102, p. 76.

of Wilmington mountain in a moraine-filled valley between two rocky knobs of the mountain mass. It can be reached by following an old lumber road which leaves the road running from Wilmington to Franklin Falls. There are four prospect pits, two of which are the beginning of shafts in crystalline limestone and pyroxene-garnet contact rocks. The first one reached, after passing the group of recently constructed buildings, is in pale-blue, coarsely crystalline limestone which carries, besides the large graphite flake, the usual collection of silicates, garnet, diopside and occasionally a little pyrite. Cutting through this mass of limestone is a streak of garnet rock. The shaft which has been made here is perhaps 12 feet square and 20 feet deep. To the northeast in the bed of a small brook is a circular shaft sunk only to a shallow depth. This also is situated in limestone. Nearby in sharp contact with this is a black, crumbly rock composed of deep-green pyroxene and dark-red garnet. At the line of contact very large flakes of graphite have been developed and to some extent squeezed and rubbed into amorphous masses due to the slight movement that has taken place between the two contrasted masses.

Higher up the slope a shaft has been sunk in a limestone that is in part a conglomerate. This has been effected by the action of a basic pegmatite presumably of the anorthosite. The pyroxene crystals associated are often crystallographically well formed and present interesting corroded surfaces as though due to the action of vapors and solutions associated with the pegmatite. A few specimens collected of the more distinctly pegmatitic material contained hexagonal prismatic of pale-green apatite. The fourth pit is located in limestone.

The ore. The material was in a large measure the pale-blue limestone, but apparently the prospectors were interested to some extent in the contact rocks as well. Two years ago even during the winter active development work was in progress, but early in the spring of 1917 they gave up their attempts to develop the property. This prospect presents some very interesting features of considerable scientific interest, but the nature of the deposit being of the limestone-contact type rather indicates that its commercial value is slight. It would appear that the area occupied by graphitic rocks covers several acres and it might be that it might prove to be as extensive as Lead hill. It is either owned or controlled by J. E. Bliss of Tupper Lake.

Occurrences in Newcomb and Minerva

The economic collections of Columbia University contain specimens of contact graphite from these townships. Further information is not available.

The Pottersville Prospect

This property is in the township of Chester, Warren county, $2\frac{1}{2}$ miles south of Pottersville, south of Loon Lake mountain, within the North Creek quadrangle.

This limestone-contact deposit has been noted by W. J. Miller,¹ who has mapped the area in which it lies, as Grenville gneiss. It is situated under the lee of a great fault line escarpment—the southern face of Loon Lake mountain.

In the field it was found that several beds of limestone, interbedded with amphibolite and with other members of the Grenville series, are cut by a dike of pegmatite which spreads over the present surface, but probably originally was a laccolith. The dip is 25° to 30° S 78° W (magnetic). No commercial importance can be attached to this locality.

The Mammoth Cave Prospect

This property is in the township of Warrensburg, Warren county, one-half of a mile north of Warrensburg, on the east side of the International highway.

This prospect consists of an opening that has been dubbed "Mammoth cave." The cave is a natural one due to the solution of the Grenville limestone, and has been somewhat enlarged by prospectors. It is 25 to 30 feet long, following the dip of the rocks (22° N 80° E). Overlying the limestone is a mass of typical syenite. Where this rock has come into contact with the limestone a thin layer carrying graphite flakes, which are often one-eighth of an inch in diameter, has resulted. The footwall is a contact rock composed of white pyroxene and scapolite and shows specks of a brilliant emerald-green mineral whose identification is not certain.

While this prospect exhibits some rather interesting features we can dismiss it from our minds as a commercial source of graphite.

SUMMARY OF THE NORTHERN AREA

A line can be drawn across the graphite area of the eastern Adirondacks north of which will be found almost all the limestone

¹ Miller, W. J., N. Y. State Mus. Bul. 170, p. 82.

and contact deposits, while most of the bedded or blanket areas all lie to the south. It may be that erosion, more severe in the south-eastern portion of the region, has removed the contact zone rocks in the section and has carried the present surface down to the horizon of the graphite schists, while in the northern area can still be seen patches of the Grenville in which graphite has been developed by contact with igneous rocks under favorable temperature and pressure conditions.

The contact deposits of graphite are usually very striking to the layman and appear to be exceedingly rich and promising, but the writer is convinced that they are too uncertain, too pockety, and too limited in extent to pay for mining. The milling of graphite is still in the experimental stage. The bedded deposits, even though much more uniform in character, afford difficult milling problems but the treatment of contact ores is still more difficult because of their greater variability. Even granted a large deposit of this form of graphite, successful mining would be highly problematical. The early workers on Lead hill were fortunate in that they realized good prices for their product and had an unusually large deposit; and the operations were in charge of an inventive man.

The important deposits of the northern area do *not* occur in veins. It seems to be the universal opinion of graphite men in the Adirondacks that veins, carrying graphite (deposited from aqueous solutions) are common. On the contrary, they are extremely rare and are always too small to be of commercial importance. Graphite *does* occur, however, in the zone between an igneous rock and a sedimentary one. The rocks most commonly so grouped are pegmatite and limestone, which is the combination found at Buck Mountain pond, Columbia, Crown Point, the "Woodchuck" workings on Lead hill, Penfield pond, Mason, and in the Pottersville properties. Deposits have also been formed by pegmatites in contact with other members of the Grenville series; upon biotite-hornblende schists, as in the case of the Betsy Cook and Towne prospects; upon amphibolite, as in the Young Lyon pit on Lead hill; and upon quartzite, as is found in the pits of the Columbia Graphite Company and the Fryatt workings on Lead hill.

The syenite (a granite low in quartz) has developed graphite in contact with limestone as in the Gulf and Mammoth cave prospects. And finally, the gabbro developed graphite when in juxtaposition with a variety of sedimentary rocks, as at Split Rock. The writer concludes then that most of the igneous rocks exposed in the

Adirondacks, especially the latter series, which the writer regards as of Algonian age, were capable of producing graphite upon contact (metasomatic metamorphism) with nearly all kinds of metamorphosed sediments.

That graphite is not always developed at the line of contact between an igneous and a sedimentary rock is, of course, easily observed. The question as to why we find graphite at one place and not at another is not as yet answered to our satisfaction. Some discussion of this problem will be found when we come to the question of the origin of graphite.

THE GRAPHITE DEPOSITS OF THE SOUTHERN AREA

In describing the occurrences of graphite in the northern area, where the contact type is best shown, geological details have purposely been avoided, but are, however, indispensable in treating the major deposits in the southern area.

The blanket or bedded form of ore body should be regarded as a distinct stratum of the old sedimentary rocks known as the Grenville series. This series represents a succession of marine deposits consisting of limestones, sandstones, shales, conglomerates and their intermediaries that have subsequently been folded, faulted and acted upon by earth forces of such magnitude that their original characters, mineralogical make-up and structures have been greatly changed. The ancient limestones have been recrystallized to white marbles; the sandstones to quartzites and quartz schists, and the shales and conglomerates to various schists and gneisses. The rocks that composed this great series, one of the most ancient known in the world, occur throughout the Adirondacks, but are found more extensively on the flanks of the mountains, such as in the eastern foothills.

Usually the subdivision of the Grenville into distinct beds or strata has not been attempted in mapping a quadrangle. It is, however, of great practical importance to graphite interests to know the succession (stratigraphy) of the Grenville rocks at the various properties. As the beds exposed in a given locality may represent a portion near the top or bottom of the original series, a district some distance away may expose a different portion; the order of the beds may differ in the two cases. There may also have been horizontal differences due to local conditions of sedimentation or in the degree of subsequent alteration (metamorphism), producing a different kind of rock although representing the same stratum.

It is often possible when the succession of the beds is understood for a given area, to locate the graphite bed by reference to the hanging or the footwall, although the ore itself may not outcrop, as well as to locate important faults and folds. It was found that practically the same rocks, in the same order, occur on the Dixon, Faxon and the Lakeside properties as well as at the Hooper mine. How many different graphitic ore beds there are in the area investigated is not absolutely certain, but it seems highly probable that there are at least two distinct beds.

Since the deposition of the Grenville series and subsequent alteration (metamorphism) they have been penetrated and injected by a series of igneous rocks that welled up from below, cutting them and greatly altering them. The first of these is a white, fine-grained granite strongly squeezed into a gneiss. It is rarely pure, for it absorbed while in the molten condition quantities of the overlying rock. It is almost always highly involved in and with the Grenville quartzites, having frequently soaked through the latter along the original bedding planes, giving rise to "lit-par-lit" injection gneisses. This will be referred to as the Laurentian granite.¹

Closely related to the granite in age, is a dark igneous rock here called a metagabbro. The significance of this rock and its relation to the Laurentian granite have heretofore been imperfectly known.² It is difficult to describe the metagabbro so that it can be recognized in the field, but suffice it to say that it varies from a fine-grained, dense, brown-black rock, similar to diabase or trap, to a salt-and-pepper combination, coarse grained and frequently gneissic. That some of it is later than the Laurentian granite has been demonstrated at the Hooper Brothers' and Flake Graphite Company's properties, although Cushing thinks that the greater part of it as shown generally throughout the Adirondacks is older.³ It was found to cut the Laurentian granite but is cut by the later granites. Furthermore, the Laurentian granite and the metagabbro have been folded with the Grenville series, while the later granites have not.

¹ See H. P. Cushing et al., N. Y. State Mus. Bul. 145, p. 46-47, 177-80, and Bul. 169, p. 21-26; also Am. Jour. Sci., 39:288-94.

² The writer believes that this investigation has demonstrated that the Adirondack amphibolite is in part (1) sedimentary, a distinct stratum of the Grenville series; (2) in part igneous, this metagabbro; and (3) altered, impure limestones. A careful study of all three types has shown that in the majority of cases it is possible to distinguish them. (See summary of southern area).

³ H. P. Cushing. Personally communicated.

Its typical behavior is sill-like (laccolith), often acting like a member of the Grenville strata in a given case, but frequently it cuts diagonally across the bedding. At the Hooper mine it cuts out the ore at the west end of the property after it has acted as a capping rock for a long distance.

The rocks above mentioned were folded and faulted before the intrusion of the anorthosite, as well as of the syenite, quartz-syenite, syenite-granite and granite that are different phases of related deep-seated rock masses. These syenite-granite rocks and their dikes (pegmatites) are in the main responsible for the development of the contact type of graphite already treated. In the southern area they have another significance for the miner, and that is in the way they frequently cut the ore. Such considerations are important in estimating ore reserves.

These rocks are here assumed to be of Algonian age. This correlation is merely suggested in the same way that the term Laurentian has been used.

Following the Algonian granitic rocks in time of intrusion is the long recognized Adirondack gabbro — green-black in color, often showing long, slender needles of feldspar (labradorite) and likewise referred to the Algonian.

The list of rock units is completed by the trap or diabase dikes, coal-black bands from a few inches to many feet in width, that cut all the above-noted rocks.

Thus summing up the Adirondack rocks, placing the oldest rocks at the bottom, the geological column would be:

Keweenawan, in part.....	Diabase
	{ Gabbro
Algonian.....	{ Granite
	{ Syenite
	{ Anorthosite
Laurentian.....	{ Metagabbro
	{ Granite
	{ Para-schists
	{ Para-gneisses
Grenville series.....	{ Quartzites
	{ Para-amphibolites
	{ Limestones

The Dixon and Faxon Properties

The property of the American Graphite Company and the adjoining property, owned by William H. Faxon, comprise a single district and can for the most part be treated as a unit.

Location. The Dixon-Faxon properties are located in the township of Hague, Warren county, about $4\frac{1}{2}$ miles west of Lake George on the southern border of the Paradox lake, and the northern edge of the Bolton quadrangles. The headquarters of the Dixon Company has become known as Graphite. The Faxon property is to the south and the southwest.

At the present time the Dixon Company is the most important producer of flake graphite in the Adirondacks, and possibly in the United States. Continuous mining has been pursued for over thirty years and it is largely due to this company that the production of graphite has been maintained.

The Faxon property has been extensively prospected by diamond drilling and promises to be a large producer when developed. It has been stated from time to time in the last ten years that Faxon was just on the point of commencing operations, and there is now every evidence that he will soon do so.

Geology. In order to grasp the conditions of mining, the character of the ore and the problems of supply, a knowledge of the rocks and their succession is necessary.

The ore is a quartz schist, somewhat feldspathic, containing about 5 to 7 per cent of graphite and small amounts of biotite and pyrite. It varies from a few feet to 20 feet in thickness as it pinches and swells, but the average would be about 15 feet. This stratum is so characteristic, not only here but in most of the other mines in the southern area, that it would be very desirable to give it a distinctive name. It has been impossible up to the present time to secure an ideal name. The term "Graphite schist" would, perhaps, conform to geological tradition, taking the name from the village of Graphite. As some confusion may result, in that all the bedded ores are graphitic schists, the term "Dixon schist," while open to criticism¹ is here used for convenience and should not become an established name in Adirondack geology.

It is highly probable that the Dixon schist occurs as two long lenses, which can be regarded as separate beds. It is the general opinion that as one bed thickens the other diminishes in thickness.

¹ As it is preoccupied, Dixon formation, Silurian of Tennessee; see Pete, William F., & Bassler, Ray S., U. S. Nat. Mus. Proc. 34:407-32.

These are usually separated by the same kind of rock that forms the footwall, which is garnetiferous gneiss. The American Graphite Company in its main mine is probably following the lower bed, there the thicker of the two. As the rock that forms the roof is the same as the footwall, it has been assumed that the rock that overlies the ore is garnetiferous gneiss. The writer would emphasize this fact, for some confusion has resulted from incorrect statements.¹

The upper bed of the Dixon schist is usually capped by a limestone, although this is occasionally absent. The limestone is sometimes pure but more frequently siliceous. This formation the writer chooses to call the Faxon limestone, taking the name from Faxon pond. No definite statement can be made as to the thickness, as it has been molded and stretched like so much putty under the stresses to which the whole region has been subjected, but a maximum thickness of 20 feet can be given.

The Faxon limestone is capped by a quartzite,² usually vitreous, approaching a glassy phase in certain localities. This is referred to as the Swede Pond quartzite, taking its name from Swede pond. It is probably several hundred feet thick. This is overlain by another limestone bed of crumbly texture or "sandy" to which no distinctive name has been applied.

It is followed by a sillimanite schist which the writer calls the Catamount schist,³ then by a para-amphibolite designated as the Beech Mountain amphibolite.

The footwall of the ore is extremely characteristic. It is a bluish green rock with purple garnets as large as peas. It has been found to be the footwall here, at the Hague mine, at the Hooper mine and many other localities. When examined under the microscope it is found to contain, besides quartz, feldspar and garnet, long slender needles of the mineral sillimanite. In the literature it is spoken of as a garnet-sillimanite (para-) gneiss.⁴ The term "Hague" gneiss seems to be highly appropriate and will be used here. It is some 50 or 60 feet thick on the Faxon property but decreases in thickness toward the east.

Beneath is a rock that appears to be a granite but is not a simple

¹ The Mineral Industry for 1890, p. 383. Kemp, J. F., & Newland, D. H. 51st Ann. Rep't, N. Y. State Mus., 2:539, fig. 4, section.

² Noted by Kemp & Newland, 51st Ann. Rep't, N. Y. State Mus., 2:539. See the Mineral Industry for 1898, p. 383.

³ See description of the Bear Mountain pond region and the property of the International Graphite Company.

⁴ 51st Ann. Rep't, N. Y. State Mus., 2:530. Microphotograph.

pure rock but a syntectic.¹ Careful studies indicate that the lower beds of the Hague gneiss have been "soaked" and saturated by igneous solutions of the Laurentian granite. In this syntectic rock the characteristic garnets of the former are absent but the sillimanite is still persistent. This syntectic rock is termed the Trumbull gneiss, from Trumbull mountain. The lower portions of the Trumbull are comparatively free from sedimentary admixture and approach the true Laurentian granite in character.

The summary of the stratigraphy for this district is as follows:

AGE	ROCK	NAME
Keweenawan.....	Diabase.....	.....
Algoman.....	Gabbro.....	.....
Laurentian.....	Granite.....	.....
	Para-amphibolite.....	Beech Mountain
	Graphite schist.....	Bear Pond schist
	Sillimanite schist.....	Catamount
	Limestone.....	.....
Grenville.....	Quartzite.....	Swede Pond
	Limestone.....	Faxon
	Graphite schist.....	Dixon
	Garnet-sillimanite para- gneiss.....	Hague
	Syntectic rock.....	Trumbull

American graphite mine. The great share of the mining is underground and more closely resembles coal mining than operations on a vein deposit. The extensive mining has resulted in very large chambers; the entrance drift driven into the hillside with a southwest direction, follows the strike of the Dixon schist for a distance of probably over one-half of a mile. At the far end of the opening, near the southwestern limits of the mine, the mine tracks are near the surface, but the miners have worked down the dip to the southeast one-fourth of a mile, reaching a depth of 200 to 250 feet. The roof needs little support and for that purpose is left an occasional pillar of ore. The floor of the mine is exceedingly uneven as the dip (average about 20 to 25 degrees) is not constant but varies considerably, due to irregularities of the Grenville rocks. Occasionally the Hague gneiss and the hanging wall come together, pinching out the ore. The deepest portion of the mine, now abandoned and filled with water, is known as the "big sink." The breast here is said to be barren of graphite and in character abrupt and nearly vertical. The ore here has been cut off by a fault (see below). The present mining is localized in the far south corner of the property close to the Faxon line.

¹ Suggested by Kemp, *ibid.* Used to indicate a rock composed of the admixture of two or more different rocks.

The main versus the "bastard" bed. Graphite men state that the schist mined in this locality occurs as two distinct beds. The one opened in the American mine is probably the lower one, which here is the thicker. The upper one is known as the "bastard vein."¹ Garnet-sillimanite rock (a portion of the Hague gneiss) separates them. It is the common belief that as the Faxon line is approached the main bed becomes thinner, while the "bastard" stratum increases in thickness and constitutes the ore on that property. Bastin suggests such a possibility and says:² "It is probable that the ore on the Faxon property . . . is the continuation of one or the other of the beds worked by the American Graphite Company . . . though their continuity has not been certainly traced."

The writer was not afforded an opportunity to see this for himself, although it is very reasonable in view of the known stratigraphy to assume that the beds are continuous. Which of the two beds is the important Faxon ore is not proved, but from the diamond drill records it appears likely that it is the upper bed.

On the geologic map two beds are represented; when one is thin the other is thick.

The summer pit. To the east of the outcrop of the main bed of the American Graphite Company is a northeast and southwest pit about 600 feet in length following a bed of the graphitic schist. The ore here strikes N 50° E and dips 20° to the southeast, and is parallel to the other outcrop. The pit is "shallow and operated during the summer season . . . The thickness of the bed at the mouth of the pit is from 6 to 10 feet. . . . This pit was opened about 1890. The ore is similar to"³ that in the main mine.

The relation between the two outcrops has long been in dispute. Kemp and Newland⁴ suggest that the two beds of the graphitic schist are separated by a fault causing a repetition of the beds. That such actually is the case was demonstrated by the rocks freshly exposed along the right of way of the new state road. There is a sudden change from the Swede Pond quartzite to the Faxon limestone. Exposures of the former show crushing by the slipping of the two blocks on each other. Specimens were secured that exhibit brecciated fragments recemented by the infiltration of silica. This

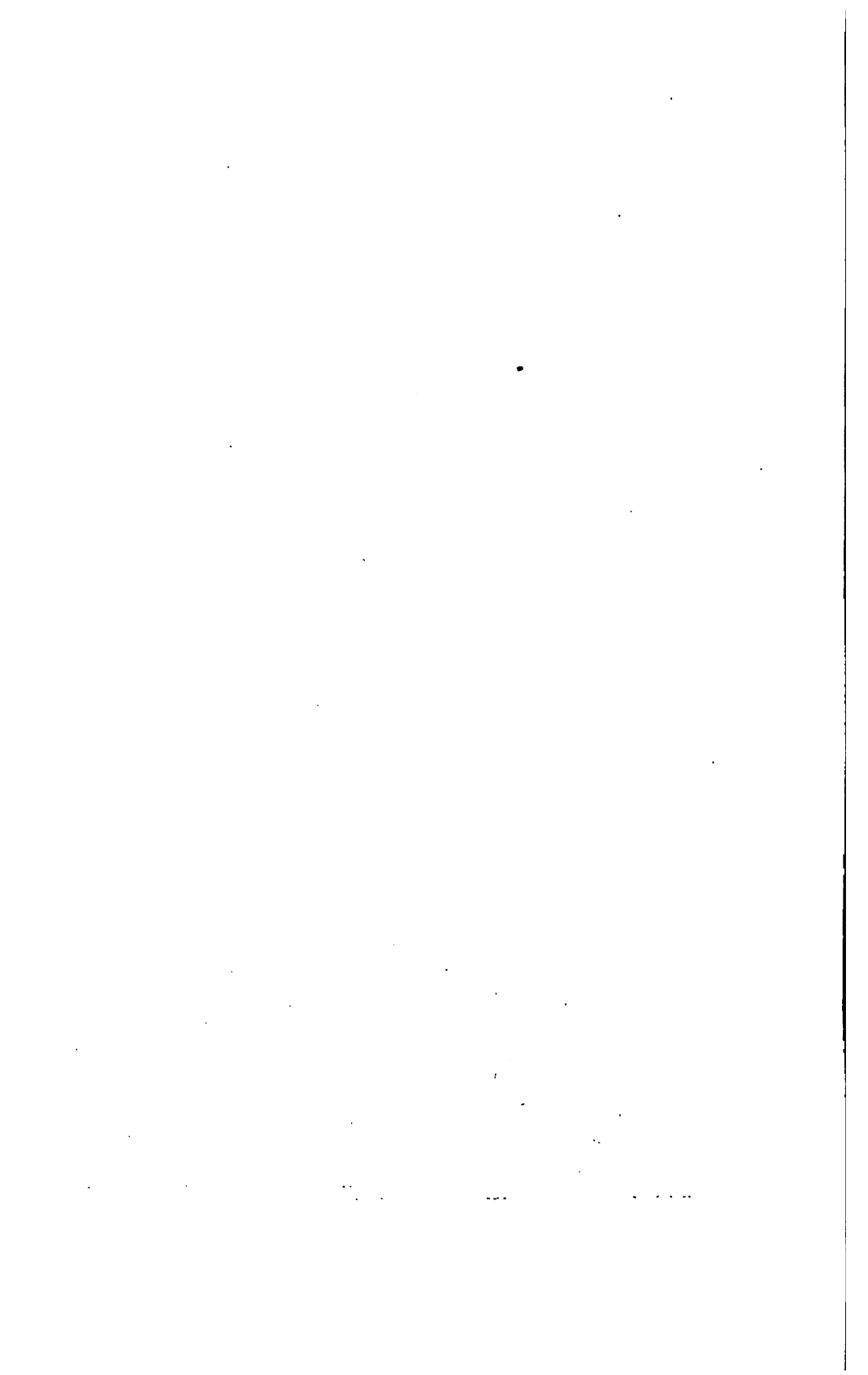
¹ The use of the term "vein" is likewise incorrect when applied to bedded deposits.

² Bastin, E. S., *Mineral Resources*, U. S. G. S. 1908, 2:725.

³ Bastin, E. S., loc. cit. p. 724.

⁴ N. Y. State Mus., 51st Ann. Rep't, 2, fig. 4, 1897, and the *Mineral Industry* for 1898, p. 383.





fault is the main "cut-off." Again to the east is a similar fault but of less magnitude. The evidence for this fault is just as positive. To the east of both, the main and the bastard beds outcrop. The thickness of the two here is apparently the reverse of that exhibited in the main mine.

The summer pit was intermittently worked for a number of years during the summer (hence the name). It has lain idle for some time until recently. Considerable ore has been mined along the strike but not much along the dip as the miners are close to the line of the Wheeler lot, of which the mineral rights are owned by W. H. Faxon. The southern end of the Summer pit bed is probably cut off by a fault. This is not proved and hence it is indicated upon the map by a dashline. It is reported that the northern end dies or pinches out. The writer had no opportunity of investigating this.

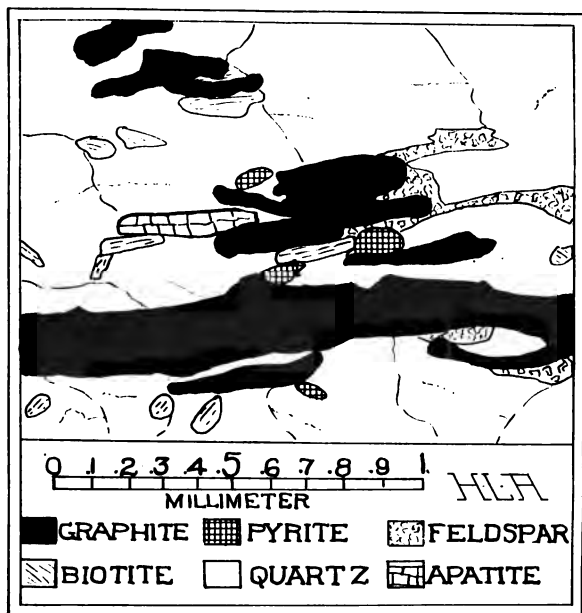


Fig. 7 Camera-lucida drawing of microscopic thin section of very high-grade Dixon ore from the main mine. (Specimen 850). H. L. Alling, 1918.

To the south of the bridge over North pond outlet an exposure of the Trumbull gneiss was found. The particular specimen examined microscopically probably represents the transition from the Trumbull to the Hague gneiss — the footwall of the graphitic schist. Thus there is the possibility of a bed, probably dipping

southward, continuing onto the lot owned by the American Graphite Company. The Algomian gabbro which outcrops so frequently on the southern edge of the area mapped has intruded the sediments as mushroom-shaped bodies (laccoliths), doming up the Swede Pond quartzite. Just where the feeding channel or channels (the "stem of the mushroom") of the mass of gabbro on the lot is of course not known, but it may be that they cut through the ore at some point underneath the surface.

The Dixon schist. This is a sedimentary rock composed of interlocking quartz grains with accessory microcline and oligoclase feldspars (usually altered to sericite), pyrite, graphite and bleached brown biotite; in part completely altered to chlorite. Occasionally a little apatite, titanite, zircon and garnet is found. The graphite is almost always associated with the biotite, usually interleaved with it, and frequently with the pyrite as well. The graphite, biotite and pyrite occur in bands parallel to the schistosity.

Chemical analysis of the American ore

	SAMPLE A	SAMPLE B	SAMPLE C
SiO ₂	65.10		
Al ₂ O ₃	9.15		
Fe ₂ O ₃	4.68		
FeO.....	3.09		
MgO.....	2.21		
CaO.....	1.17		
Na ₂ O.....	.24		
K ₂ O.....	2.32		
H ₂ O —.....	.50		
H ₂ O +.....	2.33		
TiO.....	.96		
CO ₂	None		
P ₂ O ₅	.74		
S.....	3.26		
MnO.....	.03		
C.....	5.29	Graphite... 6.25	 5.36
Total.....	101.61		
Less O.....	1.63		
	99.98		

Sample A is a composite sample analyzed by George Streiger in the laboratory of the United States Geological Survey. Collected by E. S. Bastin.¹ Sample B is another collected by Bastin (Econ.

¹ Bastin gives this analysis in Econ. Geol., 5: p. 141. F. W. Clarke, U. S. G. S. Bul. 591, p. 40, gives the identical analysis for the Adirondack Graphite Company's (Washington co.) ore. As it seems highly improbable that the schists of the two localities should be exactly alike, it seems very likely that some error has occurred in ascribing the analysis to both companies. It seems probable that this analysis was made upon the American Graphite Company's schist.

Geol., 5:137). Sample C is a composite sample analyzed by W. H. Hall in the laboratories of the Massachusetts Institute of Technology.

Quantitative microscopic analyses of the Dixon ores

			No. 751 "Bastard" bed near Summer pit state road	No. C 3-N Main mine	No. 850 Main mine	No. 851 Main mine	No. 852 Summer pit	No. 853 Summer pit
Quality			Poor	Average	Above normal	Above normal	Average	Average
APPROXIMATE COMPOSITION BY WEIGHT	Graphite		3.7	5.2	9.8	7.8	7.8	6.4
	Biotite		4.6	2.4	.3	3.8	4.4	.7
	Chlorite		.2	.7	2.0	.8	1.2	6.5
	Oligoclase-andesine		22.0	25.3	16.0	19.1	7.3	14.3
	Microcline		.4	1.4	.3	.3	.1	.9
	Orthoclase		.2	.5	.3	.1	.1	.2
	Quartz		62.6	60.8	64.4	64.5	74.5	67.0
	Pyrite		1.4	1.7	5.9	2.4	5.3	1.7
	Apatite		.6	.7	1.0	1.2	1.1	1.0
	Titanite		.3	.1	.....	.....	.1	.....
	Zircon .....		.....	.1	.....	.....	.....	.1
SIZE OF THE GRAPHITE FLAKES	Tourmaline .....		.....	.....	.....	.....	.....	.1
	Garnet		4.0	.....	.....	.....	.....	.....
	TOTAL		100.0	100.0	100.0	100.0	100.0	100.0
								
THICKNESS IN THIN SECTION	LENGTH IN THIN SECTION	Average	.32 mm	1.10 mm	1.79 mm	1.03 mm	.70 mm	.67 mm
		Maximum	.50 mm	3.50 mm	5.20 mm	2.50 mm	1.40 mm	1.42 mm
		Minimum	.20 mm	.34 mm	.30 mm	.40 mm	.32 mm	.35 mm
	THICKNESS IN THIN SECTION	Average	.014 mm	.045 mm	.050 mm	.079 mm	.056 mm	.043 mm
		Maximum	.025 mm	.074 mm	.089 mm	.147 mm	.095 mm	.070 mm
		Minimum	.003 mm	.020 mm	.020 mm	.020 mm	.020 mm	.012 mm

The Dixon schist as shown at Graphite, both in the main mine and in the Summer pit, is practically free from micaceous minerals.¹

The ore has been rubbed or squeezed to some extent, resulting in an easily disintegrated material. This is especially true in the case of certain specimens of the Summer pit ore which falls to pieces even by crumbling with the fingers. In one of the slides of the ore from the main mine (no. C3-N) some of the graphite flakes and pyrite grains were observed to be split apart, and in case of the pyrite, penetrated by a secondary fibrous aggregate, probably of sericitic mica. While the writer does not feel justified in going on record that the sericite is replacing the graphite and pyrite, it certainly appears to be the case. The pyrite has been broken up into

¹ Newland, D. H., N. Y. State Mus. Bul. 161, p. 32.

triangular shaped pieces by the slender, fibrous laths. The only similar occurrence that has been noted is the development of zeolitic minerals between the thin laminae of graphite flakes in certain contact zone rocks of the northern area.

Microscopic Analyses

In addition to the chemical analyses here quoted, a number of microscopic analyses of the graphite ores of the different graphite properties are included in this report. As this type of analyses and the method of making it is unusual, a word concerning it is introduced at this point.

The microscopic analyses were made by means of a petrographic microscope equipped with a camera lucida. By this arrangement the outlines of the mineral grains in a given field were traced upon coördinate paper and the areas occupied by the different species determined by either one of two methods. For the larger areas a polar planimeter was employed that measured the areas directly. For the smaller units the areas were secured by counting the individual squares of the cross-section paper. These two methods were used together as the paper was ruled in the same units as those recorded by the planimeter. The sum of the areas occupied by the grains of the different minerals was assumed to be proportional to their volumes. By multiplying the volumes by the average specific gravities of the minerals the proportion by weight was secured and then calculated to 100 per cent. Usually three different microscopic fields to each slide were analyzed and their results averaged. Care was taken to use an optical system (objectives and oculars) so that the largest practical field was obtained. The results of this method are only approximate and should be regarded as merely indicating the proper order of magnitude. In case of the graphite special pains were taken to secure as accurate a result as possible. For this mineral the probable error is likely about ± 1 per cent while for the more abundant minerals an error of ± 2 per cent to ± 3 per cent at least can be expected. It has not been possible up to the present to check these results against a chemical analysis, for a given hand specimen of this sedimentary schist is variable and any two specimens, even if taken from the same spot, will show slight differences in mineralogical make-up.

The measurements made upon the graphite flakes were secured in a similar manner, using the camera lucida. A scale, adapted for the particular optical system employed, was moved into position

so that the images of the flake and the scale coincided. The maximum and minimum diameter of each of ten normal flakes was measured in this way and the results averaged. The thin sections of the graphitic schists were cut perpendicularly to the plane of the schistosity and thus the graphite flakes appeared as long laths. The length of these is a measure of the diameter of the flakes. The average length is the result of ten measurements. The width of these laths gives the thickness of the flakes. Other measurements have been made upon flakes brushed off from hand specimens and laid flat upon a microscopic slide. The concentrates were treated in this same manner. All these measurements are fairly accurate.

The mill. The ore from the mine is hauled directly into the mill. The concentration process is by the usual Adirondack wet method. The process is briefly described as "crushing, rolling," stamping by a battery of California stamps, "and buddling to a 70 per cent concentrate."¹ "The concentrates are said to average about 3 per cent by weight of the ore mined."² . . . "The average output of the mine is 160 to 180 tons a day."³ . . . "The milling process is kept secret."

The American Graphite Company concentrates

GRADE	COARSE FLAKE	FINE PRODUCT
Average diameter	.37 mm x .62 mm	.015 mm x .021 mm
Maximum diameter	1.11 mm	.040 mm
Minimum diameter	.23 mm	.003 mm

The concentrates are hauled by motor trucks down the steep grade to Hague and there transferred to barges on Lake George which carry it to Ticonderoga for final treatment in the finishing mill there. The details of the refining process are not made public. It is reported that in 1908⁴ there were four Munson under-runner burr mills and five Abbé pebble mills in use. Further details are not available.

¹ Bastin, E. S., Mineral Resources, U. S. G. S., 1913, 2: 217.

² Kemp & Newland, 51st Ann. Rep't, N. Y. State Mus. 2: 539.

³ Bastin, E. S. *ibid.*

⁴ W. R. Ingalls, The Mineral Industry for 1908, 17: 493.

The Faxon Property

The title to the adjoining property to the south and southwest is held in fee by William H. Faxon of Chestertown.¹ The land embraces about 1300 acres. In addition is included the mineral rights on lot 229, known as the Wheeler lot, which contains about 100 acres. The nature of the ground and location of the different lots can be learned by glancing at the accompanying topographic and geological map, which is based upon an enlargement of an old forestry map.

The early workings are located about a mile southwest of the mill of the American Graphite Company and consist of a short drift driven into the face of a cliff exposed in a natural ravine (just northeast of the diabase dike, which is shown on the map) N 75° E (magnetic) for 50 feet, then turning a right angle to N 15° W for 45 feet more. The ore and associated rocks here strike N 50° E and dip 20° to the southeast.² The roof of the drift is siliceous limestone, which has been at this point overthrust from the southeast, the line of faulting being nearly parallel to the bedding planes. This is of minor importance. This fault has been pointed out by Bastin, who says:³ "There is evidence of shearing movement in the bed overlying the ore, lenses of quartz schist surrounded by crystalline limestone having been broken in several instances and the fragments dragged apart, though still preserving their angular outlines. There is also some crumpling in the more quartzose layers."

"Two distinct beds are found here separated by a band of garnetiferous gneiss (the Hague gneiss). In drill hole 2 . . . a similar relation holds, the upper bed measuring about 4 feet and the lower 18 feet with 26 feet of the garnetiferous gneiss between them. The two beds appear to merge" [or the upper bed is missing] "a little farther northeast, for in no. 3 hole . . . a single seam over 20 feet thick was encountered and this continues with local variations as to thickness to the northeast limits of the property, except in the places where the series is invaded by a gabbro intrusion"⁴ [and displaced by faulting].

Mr Newland directed the writer's attention, in the field, to the unusual, perhaps unique behavior of the diabase dike that is indicated in the southwest corner of the map. Just north of the new state

¹The Faxon property has been sold to a Long Island party. It is understood that the property will be worked by the American Graphite Company.

²Bastin, E. S., *Mineral Resources*, U. S. G. S., 1908, 2:724.

³Loc. cit. p. 725.

⁴Newland, D. H., *N. Y. State Mus. Bul.* 142, p. 37-38, 1910.

road the dike is exposed with a width of 40 feet, penetrating the thicker member of the Dixon schist on the south side of the road; but instead of behaving in a normal way and reaching to the surface it has expended its energy in splitting this seam by forming a large mushroom mass (laccolith) about 270 feet in length. This unusual laccolithic mass is chiefly confined to the west side of the main body of the dike. The rock itself is normal Adirondack diabase, olivine free, exhibiting chilled margins and is being quarried for surfacing the road.

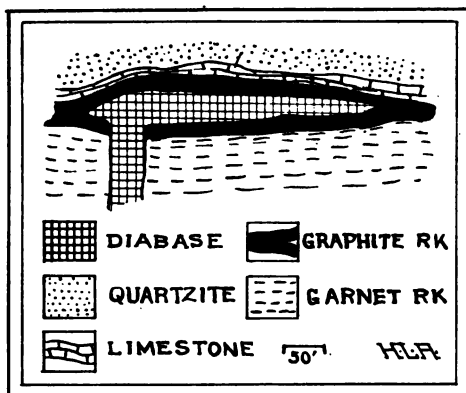


Fig. 8 The laccolithic diabase dike on the Faxon property, not far from the old workings. The new state road has cut through this mass of diabase, revealing the fact that the dike formed a laccolith which splits the Dixon schist. Looking south. H. L. Alling, 1917.

Just back of the camp and running northwest is a fault, recognized by Mr Newland, that offsets the ore, as can be seen from the geologic map. Across Faxon pond to the south another fault is indicated cutting across Swede Pond mountain. As these two faults are drawn it would appear that they are separate affairs, but it is quite possible that a little more care in the field would reveal the fact that it is the same fault. From a study of the drill records kindly furnished by Mr Faxon, although difficult of interpretation due to insufficient data, the writer suggests the possibility of a fault of small displacement running from hole 4 in the Wheeler lot southwest through the ponds between holes 3 and 7 (of the Faxon group). This is the North Pond fault. Another, trending east and west from hole 7 continued to the old road, where well-defined

slickensides occur in the Algonian gabbro. Although these faults upstep the ore each time to the southeast, the ore apparently is dipping with more or less regularity and continues from lots 228 and 230 to lot 231.

Secondary to the interest taken in the possibilities on lots 228, 230 and 231, the Wheeler lot has received considerable attention. The Summer pit bed continues onto the Wheeler lot, as is shown by the drill records of holes 1 and 2, where $15\frac{1}{2}$ and 5 feet of ore is found respectively. Hole 3 went down 232 feet without finding any graphite. It may be that hole 3 was beyond the eastern limit of the ore as the Summer pit bed thins or pinches out to the north, as previously suggested, or that the schist takes a pronounced roll and was not reached by the drillers. Holes 4 and 5 failed to strike any ore. Six feet north of hole 4 is a ledge of the Swede Pond quartzite, a ledge of the Swede Pond quartzite,

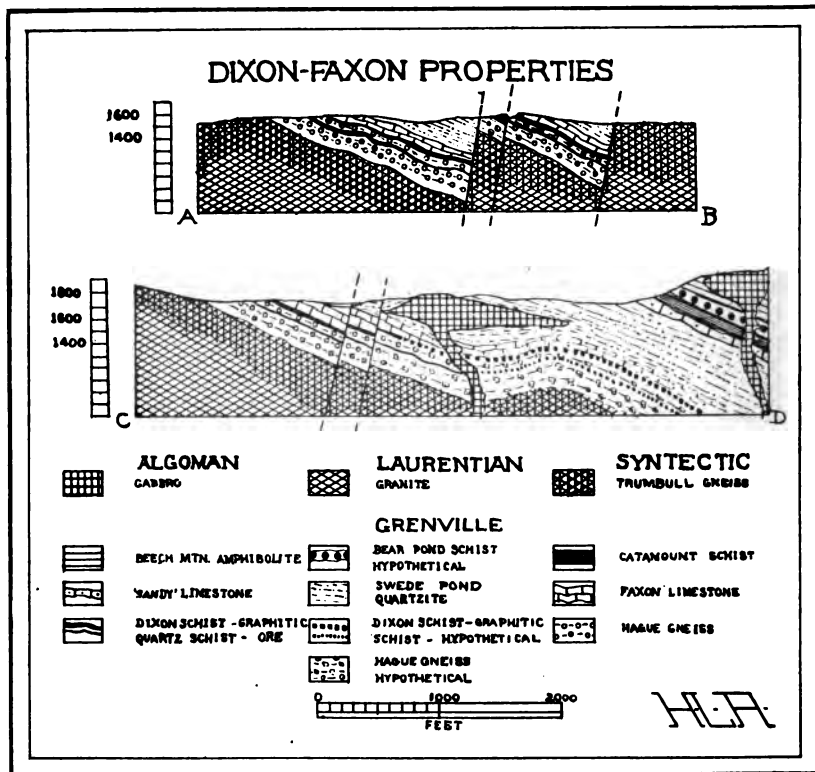


Fig. 9 Geologic reconnaissance cross-section of the Dixon-Faxon properties, showing the normal faulting and the laccoliths of the Algonian gabbro. Ratio of vertical to horizontal scales 1 : 1. Geology by H. L. Alling, 1917.

while the record gave 48 feet of hardpan and gravel and a succession of rocks which is quite different from the expected stratigraphy. The writer interprets this in the light that drillers encountered a crush zone—the North Pond fault. The tally sheet of hole 5 is valueless for the purpose of identifying the horizons, as it states 284 feet and 6 inches of “rock.” It makes a big difference whether it is the Swede Pond quartzite (a rock above the ore) or the Trumbull gneiss (a rock beneath the ore). In the vertical section (A-B) it is thought that the latter condition is the more correct one in view of the occurrence of the Trumbull gneiss at the bridge over the outlet of North pond and hence no ore can be expected to the east of the North Pond fault in line with the section, but there is the possibility of some south of this, as has been suggested when describing the Dixon property.

The American Graphite Company has in the Summer pit the most feasible approach to the ore. It would be less expedient to tap the ore on the Wheeler lot by a shaft because that would entail hoisting and pumping.

There is no question but that the ore on the Wheeler lot is of high grade. Bastin¹ describes it as follows: “Under the microscope quartz in irregular interlocking grains is seen to be the most abundant mineral. Feldspar, in part plagioclase and in part microcline, also occurs, but has suffered considerable alteration. Brown biotite in small quantities, as are also small rounded prisms of apatite. Graphite occurs in plates averaging about 0.45 millimeters in length and about 0.075 millimeters in thickness.”

The natural surroundings are favorable for mining and milling operations. Access to the Faxon bed may be had on the line of outcrop or by vertical shafts below the surface exposures. The depth to which these would have to be sunk would not exceed more than 300 feet until the less available reserves were sought.

Access to the deposit on the Wheeler lot can be had only through a shaft, as the outcrop is on the Dixon land. The new state road, now nearing completion, places this lot within easy reach.

An abundance of water can be had from the ponds, but if extensive excavations are made underground Faxon and North ponds will probably be drained. It is expected that mill water can be had from Swede pond by constructing a syphon over the low divide, piping it to the mill, where the wet process of concentration will probably be used.

¹ Bastin, E. S., Mineral Resources, U. S. G. S., 1908, 2:724-25.

The transportation facilities of the Faxon property are excellent. The new state road will make the haulage problem to and from Riparius (Riverside) station on the Adirondack branch of the Delaware and Hudson a matter of 22 miles of easy going for a motor truck.

Quantitative microscopic analyses of the Faxon ores

			No. 726 Old drift	No. 838 Outcrop, main bed east of reservoir near top	No. 854 South- west	No. 855 South- west	No. 856 Main bed outcrop	No. 857 Main bed outcrop	
Quality			Good quality	Poor quality	Good quality	Good quality	Average quality	Average quality	
APPROXIMATE COMPOSITION BY WEIGHT	Graphite		8.5	4.2	8.7	8.1	6.7	6.8	
	Biotite		3.1	.....	3.2	3.0	.9	2.3	
	Chlorite		1.4	72.7	1.9	1.7	10.4	8.7	
	Oligoclase-andesine		19.4	11.0	20.8	7.8	20.1	17.5	
	Orthoclase		4.1	.6	.4	.....	.7	.....	
	Quartz		58.5	7.0	57.9	74.4	57.9	57.0	
	Pyrite		4.0	3.9	5.8	3.2	1.7	2.1	
	Apatite		1.0	.4	1.3	1.8	1.6	1.3	
	Titanite .....		.....	.2	.....	.....	.....	4.3	
	TOTAL		100.0	100.0	100.0	100.0	100.0	100.0	
SIZE OF THE GRAPHITE FLAKES	THICKNESS IN THIN SECTION	LENGTH IN THIN SECTION	Average	.44 mm	.53 mm	1.20 mm	.75 mm	.66 mm	.69 mm
			Maximum	.80 mm	1.00 mm	2.70 mm	1.50 mm	1.10 mm	1.60 mm
			Minimum	.20 mm	.20 mm	.60 mm	.20 mm	.25 mm	.30 mm
	THICKNESS IN THIN SECTION		Average	.033 mm	.025 mm	.050 mm	.050 mm	.051 mm	.054 mm
			Maximum	.080 mm	.042 mm	.090 mm	.120 mm	.095 mm	.095 mm
			Minimum	.020 mm	.010 mm	.010 mm	.020 mm	.025 mm	.023 mm

The Faxon properties include a power site on the Schroon river, where it is understood that a dam is already in place which is able to furnish from 500 to 1000 horsepower. This available power would ensure great economy over a steam plant.

Estimate of tonnage. It is a matter of some difficulty and uncertainty to arrive at an estimate of ore reserve. A much more detailed survey, including the making of an accurate topographic and geologic map, would be necessary before accurate determinations can be made. Calculations based upon the data at hand would indicate that there are some 5,000,000 tons of ore that are more or less available.

The Lakeside Mine of the American Graphite Company

Location. This mine is located near the shore of Lake George, just back of the Trout House at Hague, township of Hague, Warren county.

The American Graphite Company opened this mine many years ago. The property represents one of the first occurrences of graphite quartz schist in New York State and possibly in the country to have been exploited.

The workings consist of two parallel drifts driven for a considerable distance due magnetic north, nearly parallel to the strike, which is N 20° W. How far these extend is not known, as it was impossible at the time of the visit to explore them for more than several hundred feet on account of water. The two are about 50 to 60 feet apart and the easterly one is 15 feet higher than the other. They are nearly horizontal but gradually slope downward so that free drainage becomes impossible. How extensive the underground operations are is not known. The upper drift is entered also by a slope about 100 feet from the portal.

Geology. The stratigraphy is strikingly like that of the Dixon and Faxon properties, but with minor variations. The graphite bed is a single stratum of the Dixon schist 12 to 15 feet thick. The footwall is the Hague gneiss in its typical development,¹ which in turn lies upon the Trumbull gneiss, which rests upon and holds inclusions of a para-amphibolite. This hornblendic rock is better shown at the Hooper mine, where it is named the Dresden.

The hanging wall is different from that found at the Dixon and Faxon properties, as the Faxon limestone is absent. Specimens taken just above the two portals appear to be the Dixon schist minus graphite. Quartz is the dominant mineral with accessory feldspar, which is entirely altered to sericite and traces of pyrite, chlorite, apatite and titanite. A little higher up, however, this quartz schist becomes very feldspathic until a true feldspar-schist ("arkosite") is found. The feldspar is chiefly soda-microcline. An abnormal percentage of titanite (CaTiSiO_5) suggests that some igneous influence has been at work. Again it is possible that this feldspar schist is equivalent to the Faxon limestone or that the limestone possibly is not represented. In stratigraphic geology a change in character of equivalent beds is usually thought to be the result of different conditions obtaining at the time of deposition; for example,

¹ Kemp, J. F., U. S. G. S. Bul. 225, p. 513.

deep water versus near-shore conditions. But in dealing with recrystallized sediments the degree of metamorphism enters as a factor to render the problem more complex. The absence of the Faxon limestone seems to be confined to the eastern edge of the area. As we shall see, this bed is wanting in nearly all the mines in the South Bay district. Does this mean that the old shore of the Grenville sea was to the east, that is, as far as Faxon time is concerned?

This feldspar-schist grades into the typical Swede Pond quartzite. Higher beds than this formation are not shown in the vicinity of Hague. There is no question in the writer's mind that the Lakeside mine exhibits the same graphitic bed now being worked at Graphite.

The ore. The ore is very similar, if not identical, in character to the Dixon schist shown on the Dixon-Faxon properties. The specimens collected are exceedingly low in mica and unusually high in graphite which may run as high as 10 per cent.¹

¹ Ihne, F. W., *The Mineral Industry*, 1908, p. 432.

Analyses of the Lakeside ores

CHEMICAL ANALYSIS		QUANTITATIVE MICROSCOPIC ANALYSES			
			Lower portal	Higher portal	Ore dump
No. 2569			No. 758	No. 761	No. 765
SiO ₂ 76.37 Al ₂ O ₃ 6.75 Fe ₂ O ₃ } 1.66 FeO..... } MgO..... .91 CaO..... 1.42 Na ₂ O..... 1.04 K ₂ O..... 1.32 H ₂ O..... .38 H ₂ O+..... 1.22 TiO ₂ 59 CO ₂ none P ₂ O ₅ 74 S..... MnO..... FeS ₂ 3.54 C..... 4.63 TOTAL..... 100.08	APPROXIMATE COMPOSITION BY WEIGHT	Graphite.....	9.1	9.6	.....
		Biotite.....	.2	.2	.....
		Chlorite.....	.2	.2	.....
		Feldspar.....	8.0	7.5	.....
		Quartz.....	72.5	81.2	.....
		Pyrite.....	9.1	1.0	.....
		Apatite.....	.9	.3	.....
		TOTAL.....	100.0	100.0	.....
		SIZE OF THE GRAPHITE FLAKES	DIAMETER IN HAND SPECIMEN	Average.....	.69 mm x .80 mm
		LENGTH IN THIN SECTION	Maximum.....	1.15 mm	1.50 mm
		THICKNESS IN THIN SECTION	Minimum.....	.54 mm	.42 mm
		Average.....	.71 mm	.91 mm	.....
		Maximum.....	1.20 mm	1.90 mm	.....
		Minimum.....	.30 mm	.40 mm	.....
		Average.....	.073 mm	.060 mm	.....
		Maximum.....	.090 mm	.125 mm	.....
		Minimum.....	.050 mm	.020 mm	.....

The chemical analysis by Chase Palmer in the laboratories of the United States Geological Survey, U. S. G. S. Bul. 591, p. 40.

The quantitative microscopic analyses by camera-lucida-polar planimeter method. These are approximate values by weight.

The exact cause of the abandonment of the Lakeside mine is not known to the writer, but the suggestion has been made that when the drifts extended below the level of the portals so that the water had to be pumped, the company ceased work and confined its attention to the deposit at Graphite. From what the writer observed there appears to be plenty of ore still unmined and it is quite possible that interest may be renewed in this locality.

The mill, which has been partly demolished, used the dry method of concentration, employing Hooper air jigs.

The Bear Pond Mountain Region

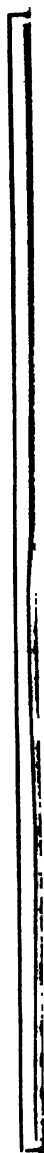
The Bly and Rock Pond Properties

Location. This district is situated in the township of Ticonderoga within the Paradox Lake quadrangle. The Bly property is on the northern and southwestern slopes of Bear Pond mountain. The Rock Pond mine is located on the shore of Rock pond to the southeast of the other. As the two properties are close together and each shares in the same geological conditions, they have been mapped as a single unit and will be described together. The properties can be reached by a road leading west from Chilson, following a fairly good dirt road to a farmhouse just north of the junction of Putnam creek and Bear pond outlet. From there a wood road leads to Bear pond. On the shore of the pond are the camp buildings belonging to Mr John D. Bly of Crown Point, who is the owner of the graphite property.

The Bly pits. The road on the north side of the mountain follows the outcrop of the graphitic schist, which here stands on edge with nearly vertical dip. A number of prospect pits have been opened to test the extent of the graphitic strata. The most important is the Eutoka pit. Near the end of the north road is the Joan pit. Mr Bly has not traced the stratum any farther to the west. South of the Joan pit on the other side of the hill is the South Side pit. The stratum here exposed has been regarded by Bastin¹ as another and distinct bed, but careful examination in the field shows that the two exposures very probably exhibit the same bed that has been isoclinally folded. The Bly property is still undeveloped.

Rock pond. In 1901 Gray Brothers began to develop a deposit at Rock pond. A well-designed ten stamp mill was erected during the following year by the Ticonderoga Graphite Company, organized for the purpose of working it. In 1903 the Ticonderoga Company allowed the Columbia Graphite Company, which had abandoned its former location near Overshot pond, to experiment with the deposit. In the following year the Rock pond property was formally taken over and worked during 1904 and 1905 by the Columbia Graphite Company, backed by Pittsburgh capital. The next year the plant was leased to Pettinos Brothers of Bethlehem, Pa., who worked it for only a brief period as the ore was cut off by a fault, it is said.

¹ Bastin, E. S., *Economic Geology*, 1910, 5:141.



Rock pond workings. These consist of an abandoned pit about 150 feet in diameter and 40 feet deep, filled with water, and a drainage tunnel. The rock is chiefly a feldspar schist (an "arkosite"¹) carrying graphite and heavily impregnated with pyrite which carries traces of galena. The oxidation of the former mineral to various oxides, hydroxides and the sulphate of iron has deeply stained the walls of the pit with reds, yellows and browns, with splashes of white incrustations of copperas.

Geology and structure. The geology in essence is not very complicated but with the isoclinal folding and subsequent compression followed by igneous injection, the structure is very involved.

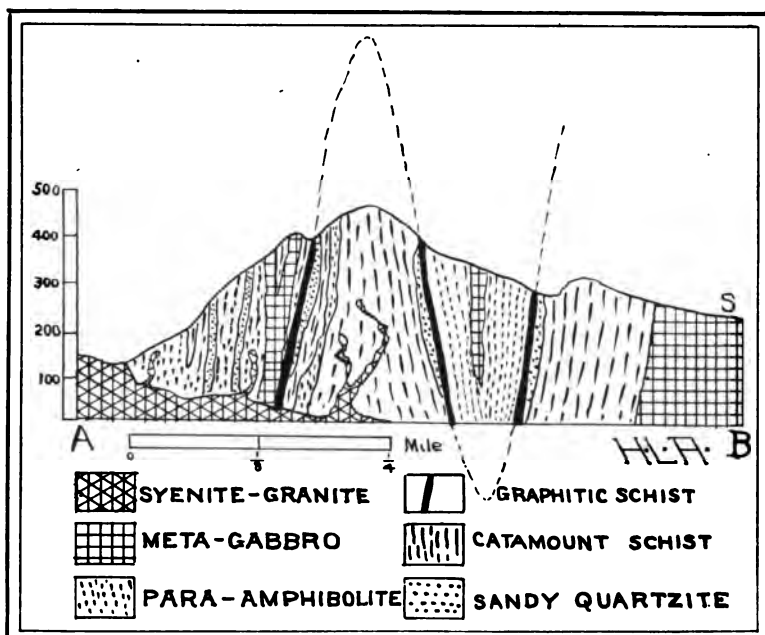


Fig. 11 Vertical section of the Bear Pond Mountain region, showing the isoclinal folding of the Bear Pond schist and associated rocks. H. L. Alling, 1917.

Bear Pond mountain is probable an anticline (see section, figure 11), while the south side of the hill is a syncline, both strongly pitching westward. These folds have been truncated by erosion, so the line

¹ The term arkose is the "special name for a sandstone rich in feldspar fragments, as distinguished from the more common, richly quartzose varieties," (Kemp, J. F., "Handbook of Rocks," 1911, p. 187). The term "arkosite" is proposed to signify an arkose that has been metamorphosed into a rock analogous to quartzite.

of outcrop of the graphitic schist (called for our purpose the Bear Pond schist) follows a Z-shaped pattern on the map.

Grenville stratigraphy. The folding and compression make it difficult to be sure of the succession of the different beds. The lowest member exposed, however, is limestone, which is found in one place near the camp. It may be equivalent to the "sandy" limestone shown on the southern edge of the Dixon and Faxon map. The next formation is the sillimanite schist called the Catamount schist from Catamount mountain near the International Graphite Company's property west of Pottersville in Warren county. In the hand specimen the long prismatic needles of the mineral sillimanite are shown.

The next rock is the Bear Pond schist — the graphitic member. It is uncertain how thick this formation is, but it is about 30 feet. Frequently this grades into a biotitic schist. Above the ore, stratigraphically, is the amphibolite, very possibly the Beach Mountain rock of the Faxon property. In mapping the Bear pond region it was often impossible in the field to distinguish this from the metagabbro and so the two rocks have been mapped together. With the microscope one can frequently distinguish them. Interbedded in the amphibolite are numerous lenses, lentils and drawn-out masses of sandy quartzite and sillimanite schist. It is doubtful if these can be ascribed to any definite place in the stratigraphic table.

Several igneous rocks are shown here. The first one to be noted is the metagabbro. Petrographic examination reveals that it was an augite monzonite; now it is a hornblende-feldspar (ortho-) schist. It was injected into the sedimentary strata before the isoclinal folding took place. Many small knobs puncture the Catamount schist, frequently exhibiting contact effects on the margins. This rock is much in evidence in the vicinity of Rock pond, where it has injected the "arkosite" in "lit-par-lit" fashion.

After the folding and lateral compression the area has been invaded by the Algoman syenite and granite. Very often this rock has absorbed, through assimilation, various members of the Grenville series, forming syntectonic rocks. Numerous pegmatite bosses cut all rocks shown on the map. On the eastern slope of the mountain the Catamount schist is cut to pieces by them in such a manner as to indicate that the main body of the syenite granite is not far below the present surface.

Bear Pond Mountain column		
AGE	ROCK	NAME
Algonian.....	Pegmatite.....	.....
	Granite.....	.....
	Syenite-granite.....	.....
	Quartz-syenite.....	.....
Laurentian (?).....	Metagabbro.....	.....
	Para-amphibolite, in which are interbedded lenses of sandy quartzite and sillimanite schist.....	Beech Mountain
Grenville.....	Graphite feldspar-quartz schist.....	Bear Pond schist
	Sillimanite schist.....	Catamount schist
	Limestone.....	.....

Faults. There are two main faults that cut across the area, each resulting in a physiographic depression. As the strata are nearly vertical, the amount of vertical displacement is not known but the lateral displacement of the Bear Pond schist and associated beds is 20 to 40 feet. The faults trend in such a direction as strongly to suggest that they nearly converge at the Rock Pond pit. At the western end of the Joan loop the graphitic bed has been greatly dissected and broken apart, probably by cross-faulting and perhaps by injections of the metagabbro. In the vicinity of Rock pond the faults are of frequent occurrence and very puzzling to trace in detail.

The Bly property.¹ The Bear Pond schist is a bedded deposit which probably has no connection with the Dixon schist. Its place in the general geological column is tentatively suggested as between the Catamount schist and the Beech Mountain amphibolite.

The Eutoka pit. This is a narrow trench dug along the strike of the bed and reached by a short adit. The rock is usually soft, due to surface weathering. This Bly has experimented with and has produced some good concentrates.

Bly concentrates

	No. 638d	No. 638b	No. 638c
	EUTOKA PIT	EUTOKA PIT	EUTOKA PIT
Average diameter.....	.64 mm x 1.12 mm	.46 mm x .77 mm	.052 mm x .067 mm
Maximum diameter.....	1.40 mm	1.30 mm	.130 mm
Minimum diameter.....	.32 mm	.20 mm	.020 mm
Estimated per cent			
Graphite.....	Nearly 100	80.0 ²	12.0
Biotite.....	.....	12.0	28.0
Quartz and feldspar.....	.....	8.0	60.0

¹ This property is sometimes referred to as the "Jumbo Mine."

² A chemical analysis by H. F. Gardner gives 77.04 per cent of graphite carbon.

The rock has been severely squeezed to an amorphous (really microcrystalline) condition. The percentages of mica and clay substances furnish a serious problem in the matter of separation. The pits farther west, designated as no. 1, no. 2 and the Joan pits, show nearly the same characters, but the rock is not much weathered, while the South Side pit shows some variation. This difference leads Bastin¹ to think that the north and south beds were different

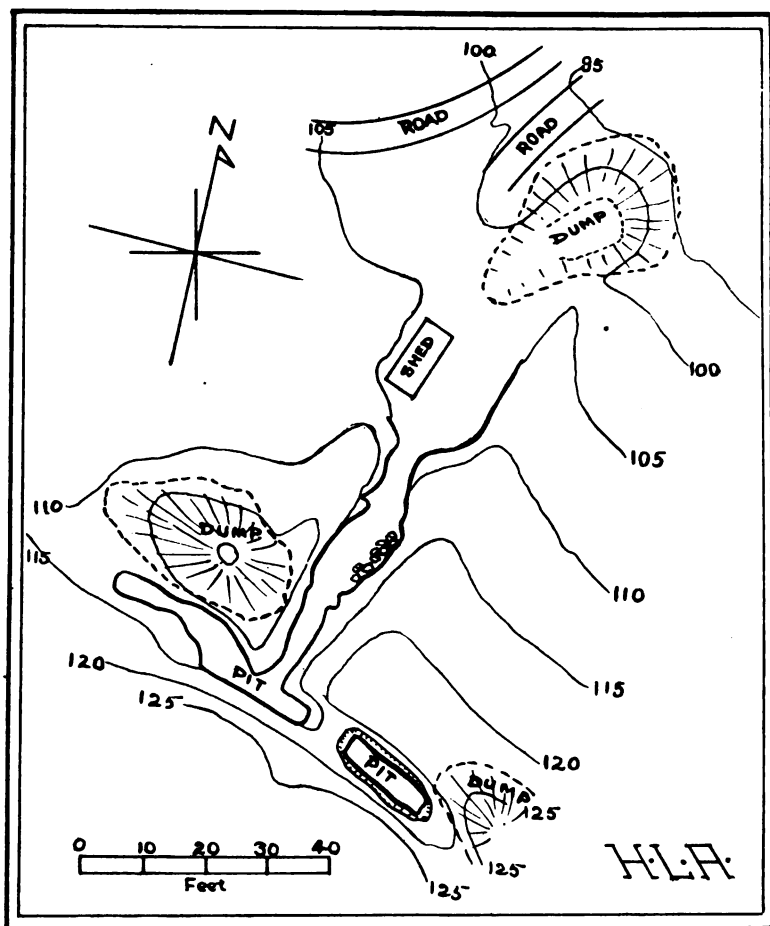


Fig. 12 Plane table map of the "Eutoka" pit on the Bly property. G. H. Chadwick and H. L. Alling, 1917.

and distinct. But it must be remembered that although today they are near together they were separated by one-fourth of a mile at

¹ Bastin, E. S., Mineral Resources, U. S. G. S., 1908, 2:726.

least before being folded, so that lateral differences in deposition may well account for this.

The Bear Pond schist. The northern arm of the Z-shaped outcrop of the graphitic schist is a feldspar-quartz-biotite graphitic schist. The feldspar dominates over the quartz while the mica, usually phlogopite and biotite, altered in part to chlorite, exceeds the amount of the graphite present. In the table showing the results of quantitative microscopic analysis, the percentages by weight of the constituent minerals are only approximate, but it is believed that they are of the proper order of magnitude. The minerals present in very small amounts and secondary alteration (katamorphic) products are purposely omitted. To a very large extent the feldspar is plagioclase almost entirely changed to secondary products, chiefly sericite. Likewise the phlogopite and biotite are weathered partly to chlorite and serpentine. Not all the quartz was an original constituent of the arkosic sands of which the Bear Pond schist is the metamorphic equivalent, for there has been an introduction of silica. The graphite is entirely distinct from this and its period of development must antedate this activity.

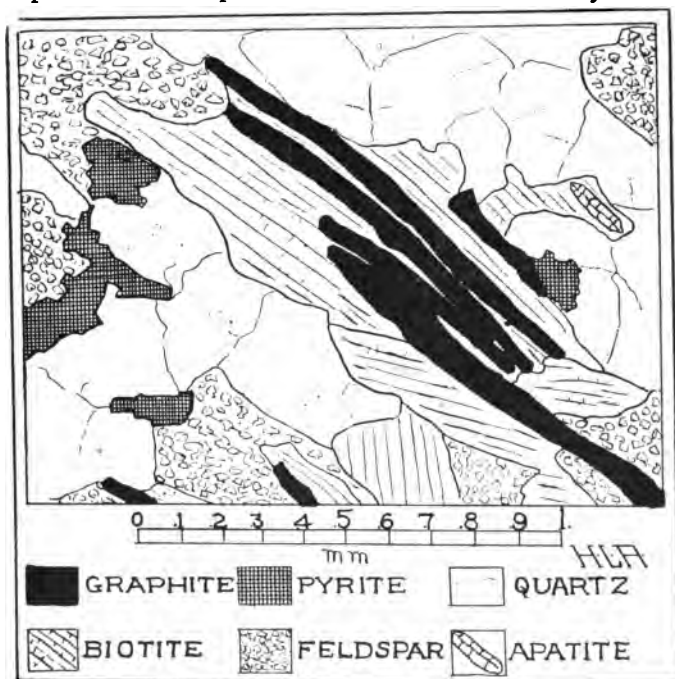


Fig. 13 Camera-lucida drawing of microscopic thin section of Bear Pond schist from the "No. 2" pit, showing the interweaving of the chloritic biotite and the graphite flakes and the introduced pyrite. X 100. H. L. Alling, 1918. (Specimen No. 847).

The graphite occurs as elongated, oval to irregular shaped flakes, nearly all of which are parallel to the schistosity of the rock, frequently interleaved and surrounded by mica and pyrite. The latter mineral has clearly been introduced at two different periods. The flakes very often bridge across the grains of quartz or feldspar. In the crushing of such ores the attrition of the flake is likely to occur. The cross-sections of the flakes, as seen in the microscopic slides

Quantitative microscopic analyses of the Bly ores

			Eutoka pit	1 pit	2 pit	Joan pit	"South Side" pit
			No. 639 845	No. 846	No. 847	No. 640 848	No. 641 849
APPROXIMATE COMPOSITION	Graphite.....		6.5	6.5	5.5	6.0	6.5
	Mica.....		10.0	10.8	11.5	11.0	10.8
	Feldspar.....		40.0	64.2	57.0	59.5	27.5
	Quartz.....		33.5	10.8	14.5	18.5	53.0
	Pyrite.....		10.0	7.7	11.5	5.0	2.2
	TOTAL.....		100.0	100.0	100.0	100.0	100.0
SIZE OF THE GRAPHITE FLAKES	Species of feldspar		Andesine oligoclase	Andesine microcline	Plagio- clase	Plagio- clase	Ortho- clase
	DIAMETER IN HAND SPECIMEN	Average.....	1.23 mm	1.20 mm	.73 mm	.85 mm	.94 mm
		x	x	x	x	x	x
		1.44 mm	1.37 mm	1.25 mm	1.35 mm	1.41 mm	1.41 mm
		Maximum.....	1.50 mm	1.84 mm	1.50 mm	2.00 mm	1.80 mm
		Minimum.....	.90 mm	.80 mm	.65 mm	.65 mm	.75 mm
	THICKNESS IN THIN SECTION	Average.....	.029 mm	.022 mm	.028 mm	.024 mm	.025 mm
		Maximum.....	.060 mm	.036 mm	.066 mm	.041 mm	.043 mm
		Minimum.....	.018 mm	.012 mm	.006 mm	.019 mm	.012 mm

prepared from specimens, reveal the fact that dynamic disturbances have frayed them into forms resembling horsetails. Analyses of four samples from various pits are reported by Bastin as running 6.4, 6.6, 6.2 and 8.8 per cent of graphitic carbon. "An analysis of a composite sample selected in 1904 to represent as nearly as might be the general run of the property showed about 5 per cent of graphitic carbon."¹ The ore from the "South Side" pit differs from the others in that the quartz is more abundant than the feld-

¹ Bastin, E. S., Resources, 1908, 2:728.

spar and the latter is orthoclase rather than plagioclase. Still the mica exceeds the amount of graphite present.

The graphite is not limited entirely to the Bear Pond schist, for frequently the Catamount schist exposed in contact with it contains small amounts. It is the opinion of the writer that igneous activity, in which the metagabbro and the Algomian granite-pegmatites have had a share, the latter being the more important factor, has redistributed the graphite, causing some of it to lodge in the adjacent rocks. This is particularly true of the South Side pit and the central bar of the Z-shaped outcrop.

Bastin regards the bed on the north side of the hill as having a thickness of 40 feet.¹ The writer thinks that this is a little excessive, for the graphitic Catamount schist that lies next to the Bear Pond schist is too low in graphite to be considered as a source of supply. It is thought that possibly the 40 feet includes some of the sillimanite schist.

Considerable space has been given to the description of the Bly ores, for the quantity is very great, probably equalling the tonnage of the Hooper property.

Possibilities of exploitation. There are several serious considerations to be taken into account in regard to the exploitation of the Bear Pond mountain property. In the first place, there is the high mica content, proportionately larger than that of the graphite. The usual methods of concentration do not make a clean separation of the two. "Most of the graphite plates are bordered on both sides by biotite and lie between the biotite laminae as between leaves of a book. Thus biotite crystals 0.15 to 0.45 millimeter thick may inclose graphite flakes of about one-tenth of this thickness."² It would appear to be exceedingly difficult to treat commercially this type of ore successfully by buddling. It has been pointed out that the habit of the plates to bridge different grains interferes with the chance of securing large flakes in the concentrates.

In the second place, the vertical dip would render mining operations rather difficult. Probably the most economical method would be by open cuts along the strike, starting in at the Eutoka pit, rejecting the soft, weathered material, with its high clay content, and working up the slope which would enable a gravity tramway to be employed. Offsets at the crossings of the fault lines should be looked for.

In the third place, the transportation problems are rather serious. The roads from the Eutoka pit to the farmhouse at the junction of

¹ Bastin, E. S., loc. cit. p. 726.

² Bastin, E. S., *Economic Geology*, 5:142.

Putnam creek and Bear pond outlet are rough and would require considerable improvement before being available. The property is a long distance from any railroad, the nearest station being at Ticonderoga, 9 miles away.

For success in operation it is essential that the property should be worked on a large scale and the milling and refining problems be solved by careful experimentation. The graphite product, also, might well be converted into merchantable forms at the plant.

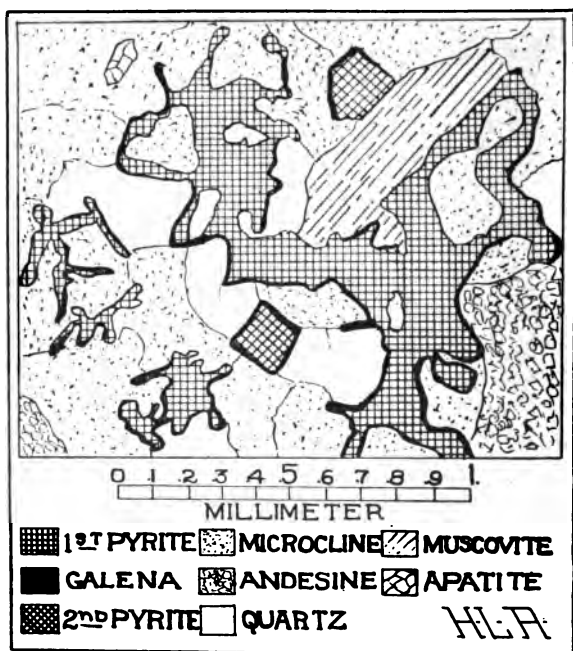


Fig. 14 Camera-lucida drawing of microscopic thin section of Rock Pond "arkosite" from head of pit, showing the two generations of pyrite and introduced galena coating the pyrite. X 100. Specimen 681. H. L. Alling, 1918.

"The plans for developing the property include erection of a mill at the mine for rough concentrating and the erection of a finishing mill at Crown Point village. Both of these mills can be run by water power, and electric power can be generated for the cheap operating of the mine machinery."¹

The Rock pond property. All that remains of this enterprise today is a big hole in the ground from which a trickle of brick-red

¹ Bastin, E. S., Mineral Resources, U. S. G. S., 1908, 2:728.

water is flowing, giving off a strong odor of copperas (iron sulphate), and the dismal ruin of a huge mill with several acres of tailings.

The geological relations exhibited here are puzzling and among the most difficult the writer has ever seen. The rock mined was a very dense, hard, fine-grained feldspathic schist (arkosite) dipping at an angle of 78° with small size flake, perhaps running from 2 to 3 per cent, and considerable amounts of pyrite and perhaps pyrrhotite. If the conditions shown on the map are correct, then

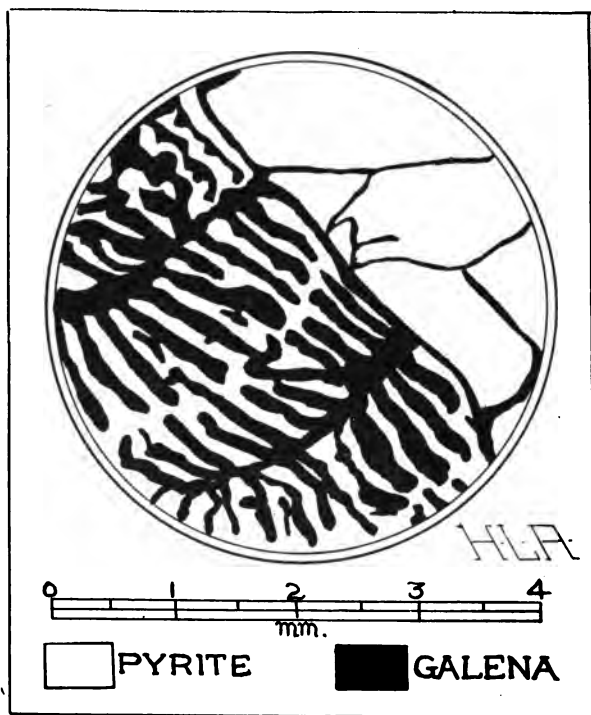


Fig. 15 Camera-lucida drawing of polished specimen of vein pyrite from Rock Pond pit, showing the microscopic intergrowths of pyrite and galena, the latter replacing the former. X 20. Specimen 650 P. H. L. Alling, 1918.

the miners were operating in a block of ore faulted on all sides. Where this rock should be placed in the geological column is a problem that can not be attempted at this time.

The graphite must be regarded as of organic origin but its relation to the pyrite, for such exists, is rather obscure. Examination shows that the pyrite is of two generations. The first introduction of the pyrite preceded the faulting, while the perfect cubes

of the mineral represent the later or postfaulting period. Polished sections of massive pyrite from a vein reveal microscopic intergrowths of galena and pyrite; the former probably replacing the latter. The percentage of the pyrite in the average rock is exceedingly high. The findings of micro-analyses are as follows: Ore from pit, 17 per cent; at head of pit, 7 per cent; rock from drainage tunnel near shore of Rock pond, 40 per cent, by weight. In addition to the pyrite disseminated through the "arkosite" there are true fissure veins, some of which are 4 to 5 inches wide. In fact, the average run of the graphite ore contains more pyrite than graphite, yet it was the latter mineral that alone was saved, the sulphide being allowed to go into the waste. If more ore should be found it would seem as if it would pay to save the pyrite for sulphuric acid manufacture.

Quantitative microscopic analyses of the Rock Pond "arkosite"

		No. 650 Drainage tunnel	No. 665 South side of pit	No. 681 Head of pit	No. 683 West corner of pit	No. 684 10 feet south of 683
APPROXIMATE COMPOSITION BY WEIGHT	Graphite.....	2.0	2.7	1.4	.4	.....
	Biotite.....	trace	trace	trace	1.4	.....
	Chlorite.....	5.0	7.4	4.6	9.0	.....
	Orthoclase.....	40.9	trace	trace	trace	.....
	Microcline.....	.7	62.2	68.4	70.0	.....
	Andesine.....	trace	2.9	trace	trace	.....
	Quartz.....	10.3	2.7	16.0	9.5	.....
	Pyrite.....	40.0	17.5	7.6	3.0	.....
	Muscovite.....	.6	.3	little	trace	.....
	Sericite.....	trace	trace	trace	5.0	.....
	Carbonates.....	trace	.3	little	1.5	.....
	Apatite.....	.3	.1	trace	trace	.....
	Titanite.....	none	none	none	.2	.....
	Augite.....	none	.2	1.8	none	.....
	Sillimanite.....	.2	none	none	none	.....
	Galena.....	.3	.3	.2	little	.....
	TOTAL.....	100.0	100.0	100.0	100.0	.....
SIZE OF THE GRAPHITE FLAKES	DIAMETER IN HAND SPECIMEN	Average.....	.57 mm	.31 mm	.....	.66 mm
			x .99 mm	x .50 mm		x .88 mm
		Maximum.....	2.55 mm	1.02 mm	.....	2.30 mm
		Minimum.....	.30 mm	.20 mm	.....	.30 mm
	LENGTH IN THIN SECTION	Average.....	.45 mm	.66 mm	.56 mm	.23 mm
		Maximum.....	.60 mm	.89 mm	.91 mm	.42 mm
		Minimum.....	.30 mm	.34 mm	.35 mm	.18 mm
	THICKNESS IN THIN SECTION	Average.....	.077 mm	.061 mm	.031 mm	.042 mm
		Maximum.....	.150 mm	.082 mm	.061 mm	.051 mm
		Minimum.....	.049 mm	.034 mm	.023 mm	.020 mm

Milling practice. The mill had a daily capacity of 3000 pounds of graphite. The ore was loaded into side-dumping cars which were hauled up an inclined track into the mill. There the ore was crushed, passed under a battery of ten California stamps, treated with water and fed to the buddles, following the usual Adirondack practice. The concentrates were hauled to Ticonderoga for shipment.

The mill has been torn down, and all the valuable material has been removed. It is difficult to express an opinion about the value of this property, but until the faults are carefully investigated and understood it would not be possible to state whether or not the ore is entirely exhausted.

Hooper Brothers' Property

Location. This recently developed property is located in the township of Dresden, Washington county, on the west side of South bay of Lake Champlain about 4 miles due west of Whitehall. Active mining operations commenced in April 1916. The establishment includes a mill, office, boarding house, blacksmith shop, etc.

Geology. In many ways the conditions that obtain here are very similar to those found on the Dixon and Faxon properties. It is quite clear that the graphite-bearing rock is the same stratum being worked at the town of Graphite.

On approaching the mill, passing the extensive tailing pond, which has been created by damming a swamp, one finds the Potsdam sandstone, a rock of Upper Cambrian age,² in sharp contact upon the yellow quartzite of the Grenville series. The mill is situated directly upon this quartzite schist which splits easily into slabs. However, this is not a pure rock but a syntectic of two. The Laurentian granite has soaked it, "lit-par-lit" injected it, so it would not be readily recognized as the equivalent of the Swede Pond quartzite. It is only rarely that an exposure can be found that reveals the original quartzite free from granitic material.

The syntectic Swede Pond gneiss directly overlies the ore, the Faxon limestone being absent. The graphite rock is the typical Dixon schist; a quartz-feldspar-schist with 5 to 6 per cent of graphite, exposed along the north road¹ and is found to outcrop for a long distance along the strike at the base of a steep cliff (cuesta front).

Beneath the ore is the rock that has been referred to as the Hague gneiss, but the garnet is not so well developed and the sillimanite

¹ Constructed in colonial days by General Burgoyne as a military road.

² Possibly of "Ozarkian" age.

is less abundant than is the case at Graphite and Hague. There is no question but that it represents the same stratigraphic unit. Beneath the Hague is the para-amphibolite, already mentioned, the dresden amphibolite. In composition, character and in habit it is similar to the Beech Mountain amphibolite, but this occupies a totally different and distinct horizon.

Two igneous rocks, both later than the Grenville rocks and which have an important bearing upon the extent of the ore, are shown. The first one to be noted is the black, gabbroic rock that acts as a cap to the long ridge running east and west. This is the so-called Laurentian metagabbro (formerly an augite monzonite) that occurs as a big sill or thin laccolith covering and replacing in part the syntectic Swede Pond gneiss. It formerly spread over a much more extensive area than is shown today, for erosion has removed large quantities, only small patches remaining. Even in the vicinity of the mill small "skins" of the metagabbro adhere to the Swede Pond gneiss. It was chilled rapidly on contact with the country rock, and specimens studied microscopically show a very fine-grained rock with diabasic texture but comparatively free from ferromagnesian minerals. To the west this cap of the metagabbro keeps cutting out more and more of the Swede Pond gneiss until it actually cuts the ore itself. This marks the westward extent of the available ore, the eastern end of the outcrop being obscured by a swamp. No one can tell where the feeding channels of the metagabbro are, nor whether they will be encountered in extensive underground operations.

One of the nice problems of Adirondack geology is the origin of the amphibolite. As has been pointed out before (in the introduction to the graphite deposits of the southern area) an "amphibolite" may be of one of three origins. The metagabbro of the Hooper property is truly igneous. The criteria used in distinguishing it from the other types are given in the summary. It remains to discuss its age relations. It lies on top of and has "lit-par-lit" injected the syntectic Swede Pond gneiss. This gneiss was previously saturated and injected by the Laurentian granite. Thus one is forced to conclude, contrary to Cushing's experience¹ that it is later in age than the Laurentian granite. Furthermore, it was found to have been folded with Grenville rocks before the intrusion of the later granite which is referred to the Algonian. It would be stretching the matter beyond the known data to conclude that all

¹ Personally communicated.

ore to the south-southeast. Kano of vertical to horizontal scales 1:1. 12. 12. running, 2222.

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igneous amphibolites (orthoamphibolites) are of the same age. Cushing believes that some are certainly older than the Laurentian granite. That may be the case with the metagabbro on Bear Pond mountain.

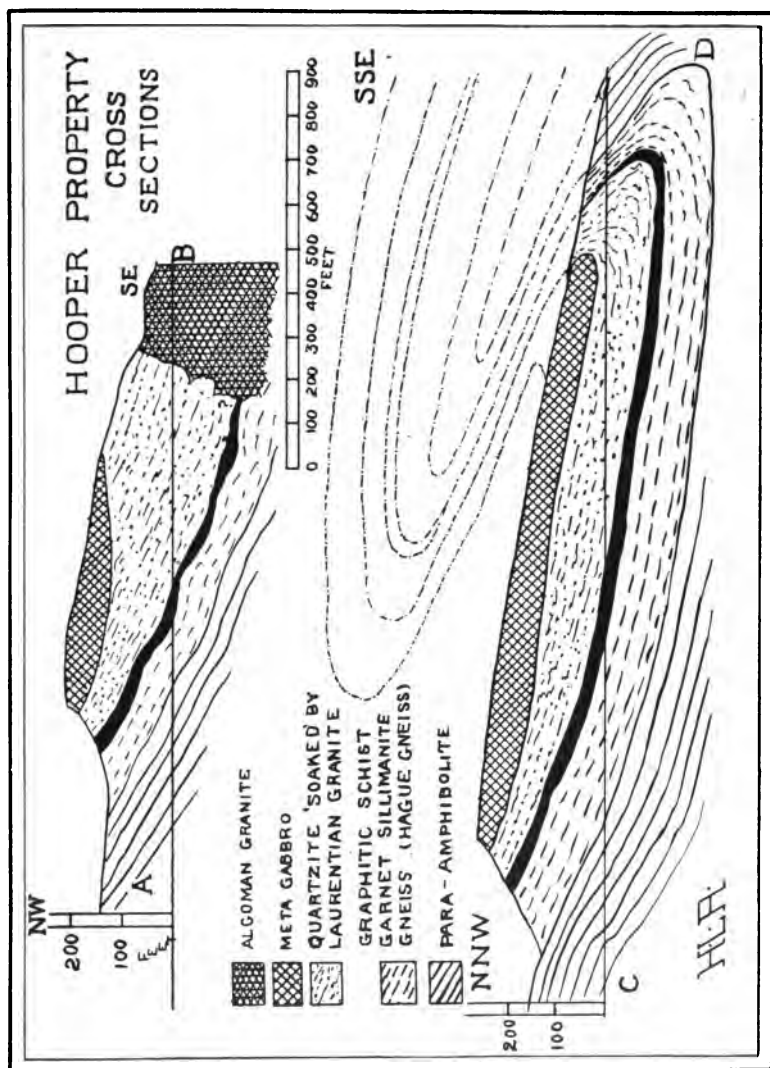


Fig. 17 Cross-sections across the Hooper property. Elevation datum surface of tailing pond. Section A-B shows the metagabbro sill as a cap and the Algonman granite cutting off the ore in depth. Section C-D shows the isoclinal folding of the rocks and the pinching out of the ore to the south-southeast. Ratio of vertical to horizontal scales 1:1. H. L. Alling, 1917.

The other igneous rock is the pink Algonman granite. A single knob is exposed on the south road. This has injected the syntectic Swede Pond gneiss in "lit-par-lit" fashion. Consequently the resulting rock is a double injected syntectic—the Grenville quartzite

saturated and injected by the Laurentian white granite and then subsequently injected by the Algonian granite. The presence of this later rock here indicates to the practical miner that it very likely cuts off the ore in depth as is shown by the vertical section. See figure 17.

Structure. The beds, including the graphitic layer, are dipping at an angle of 25° to the southeast. Considerable variation from this figure is to be expected as the dip is rarely constant for any great distance. This is well shown in the main pit. Near the eastern end a dip of 26° S 35° E was measured, while directly north of the office on the north road 32° S 18° E was noted. The twice injected gneiss on the south road was found to have the following dip: 10° S 20° E. Other observations show that the beds are probably flattening as they continue to the southeast.

Along the south road beyond the limits of the map, the quartzite, very free from the Laurentian granite, essentially the typical Swede Pond quartzite, was found succeeded by the Hague gneiss and the Dresden amphibolite in the reverse order, due to isoclinal folding; the rocks have been folded back upon themselves. The rocks all show crinkling and stretching. A careful search for the ore that normally lies between the Swede Pond and the Hague gneiss, revealed only a narrow black band with the graphite flakes stretched, rubbed and polished. The unresistant Dixon schist on close folding is stretched and pulled out into a narrow band which often breaks under such excessive strains.

In spite of this pinching of the ore and the cutting out by the Algonian granite, there is an immense amount of ore, perhaps a million and a half tons, within the property.

The ore. The graphite schist is the familiar Dixon schist very similar to the rock being mined at Graphite by the American Graphite Company. Perhaps the schist here has not been so squeezed and is harder and firmer than some of the best ore, say, from the Summer pit.

It is a quartz-feldspar combination with dominant quartz, 65 to 80 per cent, feldspar 15 to 30 per cent, and accessory graphite, biotite, chlorite and pyrite. The micro-analyses, tabulated below, although only approximate, show the relations fairly well. The ore from the main pit, which is located near the eastern limit of the outcrop, does not exhibit the best ore on the property, as is revealed by the series of test pits farther westward. The rock now mined carries a small flake which is highly involved with chloritic material. The latter is

probably derived from the alteration of micaceous minerals. Pit no. 2 shows a rock with larger flake and an almost total absence of biotite and chlorite.

Quantitative microscopic analyses of the Hooper ores

		No. 758a Pit 1	No. 721 Pit 2	No. 722 Pit 3	No. 772 Pit 4	No. C4-N	
APPROXIMATE COMPOSITION BY WEIGHT	Graphite.....	7.7	4.9	5.7	5.0	8.7	
	Biotite.....	4.7	.7	4.9	1.8	1.4	
	Chlorite.....	6.6	1.9	.....	4.8	4.5	
	Andesine.....	13.6	28.1	2.3	23.9	8.0	
	Quartz.....	64.6	60.1	82.2	58.8	75.0	
	Pyrite.....	1.2	2.2	4.9	5.7	.3	
	Anatite.....	.9	1.0	.....	.....	1.6	
	Titanite.....	.7	1.1	.....	.....	.....	
	TOTAL.....	100.0	100.0	100.0	100.0	100.0	
	SIZE OF THE GRAPHITE FLAKES	DIAMETER IN HAND SPECIMEN	Average.....	.51 mm	.68 mm	.78 mm	.51 mm
x			x	x	x	x	
.71 mm			1.18 mm	1.19 mm	.91 mm	.....	
Maximum.....		1.36 mm	1.35 mm	2.05 mm	1.43 mm	.....	
		Minimum.....	.20 mm	.40 mm	.40 mm	.35 mm	
LENGTH IN THIN SECTION		Average.....	.44 mm	.78 mm	.68 mm	.74 mm	.90 mm
		Maximum.....	.85 mm	1.10 mm	1.20 mm	1.10 mm	2.50 mm
		Minimum.....	.20 mm	.35 mm	.30 mm	.30 mm	.20 mm
THICKNESS IN THIN SECTION		Average.....	.036 mm	.037 mm	.038 mm	.046 mm	.053 mm
		Maximum.....	.050 mm	.080 mm	.059 mm	.060 mm	.150 mm
		Minimum.....	.021 mm	.020 mm	.015 mm	.030 mm	.020 mm

Microscopic measurements on Hooper concentrates

GRADE	Plus no. 8 ¹ / _{Silk}	Minus no. 8 _{Silk}
Average diameter.....	.33 x .65 mm	.17 x .23 mm
Maximum diameter.....	1.05 mm	.29 mm
Minimum diameter.....	.21 mm	.08 mm

¹ Chemical analyses by H. F. Gardner give 89.00 and 86.32 per cent graphitic carbon for these two grades respectively.

The last pit exposes the poorest grade found. It is possible that the samples secured do not represent the average run, as they may have been taken from near the top of the stratum. The texture indicates, however, that the metagabbro, which is not far away, has affected it.

Inclusions in the ore. In the main pit two or three lens-shaped masses of a tough green rock lie in and split the ore. These are known to the miners as "nuts," a very good descriptive term because of their resemblance to almonds in shape. These rock masses are often 10 feet long and 4 or 5 feet thick. Microscopic study of specimens taken from one of them shows that they are probably due to contact effects of an igneous rock upon the ore. It is very likely that they will be encountered as further development is undertaken.

Mining operations. Today the mining is confined to an open cut near the eastern limit of the outcrop. The ore is loosened by blasting, the large blocks being broken up by sledge hammers and loaded into self-dumping cars. These are run upon a turn-table and placed upon the main inclined mill track. The cars are then hauled directly into the mill by a cable system. Near the western end of the main pit a curving drift is being driven which will eventually follow the strike to the west.

Milling practice. The ore is passed through crushers, hence to two banks of California stamps. From there the pulverized rock is fed to a series of conventional buddles. The concentrates from these are then treated upon Wilfley jig tables; the final grading is accomplished upon revolving silk reels, using no. 8 silk. The concentrates are then dried and ready for shipment. The size of the concentrates, samples of which were furnished by Hooper Brothers, was measured and is tabulated above. Constant improvements and modifications in the mill and its equipment are under way and likewise plans are being made to increase the tonnage capacity of the mine and mill.

Economic summary. It is very apparent that the prospects of this property are unusually bright. There is every indication that a large supply of flake graphite may be expected from this mine.

The Champlain Graphite Company

Location. This property is situated in the township of Dresden, Washington county, on the shore of South bay across Lake Champlain from Whitehall. The property was first opened in 1904. The company was organized in 1907, but the mine was operated only a short time and is today abandoned.

Mine. The mine consists of an open pit in the face of the abrupt cliff. It is about 100 feet long and 25 feet wide and deep, partly filled with water. This cut exposes a crush zone in the graphite schist which is partly in fault contact with the metagabbro, evidently

a portion of the same mass exposed on the Hooper property. This is today a hornblende diorite.

The ore. The ore is a quartz-feldspar schist, very likely the Dixon schist, but a little lower in quartz than is the usual run. The feldspar is almost entirely weathered to secondary sericite but enough remains to demonstrate that it is largely andesine. The graphite flake is rather small and much involved with considerable chlorite and a little pyrite and biotite, reminding us of the Bly ores. The graphite flake varies "from .015 millimeter to .025 millimeter in thickness and up to 1.3 millimeters in length; the average length does not exceed 0.75 millimeter."¹ There is a lack of parallelism of the flaky minerals, due to the shearing movements associated with the faulting. The graphite is said to constitute from 4 to 7 per cent of the rock.

Quantitative microscopic analysis of the Champlain ore

No. 720
South side of pit

APPROXIMATE COMPOSITION BY WEIGHT			SIZE OF THE GRAPHITE FLAKES		
Graphite.....	5.3			Average diameter.....	.60 mm
Biotite.....	9.2				x
Chlorite.....	3.7				1.00 mm
Andesine.....	38.2			Maximum diameter.....	1.39 mm
Quartz.....	38.0			Minimum diameter.....	.28 mm
Pyrite.....	4.3				
Apatite.....	1.3			Average length.....	.76 mm
TOTAL.....	100.0			Maximum length.....	1.42 mm
				Minimum length.....	.34 mm
				Average thickness.....	.043 mm
				Maximum thickness.....	.075 mm
				Minimum thickness.....	.025 mm

The pyrite is of two generations, the early introduced type has irregular outlines becoming distinctly fuzzy at times. The later form is in perfectly bounded cubes. Both the graphite schist and the metagabbro are seamed with veins often 2 inches wide, consisting of coarsely crystalline calcite, feldspar, quartz and some garnet. The general strike of the beds is N 10° E.

The mill. A well-constructed mill which was built in 1905 stands close to the water's edge, 300 feet from the quarry with which it is connected by a short tramway. "The equipment includes a jaw crusher, 12-inch rolls, broken-screw agitators, three buddles, drying floor, bolting machines, tube mill, etc."²

Economic future. The predicament in which the Champlain Graphite Company found itself is a striking example of the disastrous results that follow the attempt to open a mine before con-

¹ Bastin, E. S., Mineral Resources, U. S. G. S., 1909, 2:823.

² Bastin, E. S., loc. cit. p. 823.

ditions are known. The geological situation is decidedly unfavorable for such an enterprise on account of the crushing of the rocks along the fault line; and the liability that the metagabbro cuts off the ore is always present. Mr Newland, who visited the property when operations were in progress, states that above the mine a considerable distance up the slope another exposure of the graphite schist occurs which is very likely an extension of the same bed, and which offers more promising conditions for a successful mine. Is the rock in the pit a downfaulted block? Thus there may be more ore in sight but it is very clear that the present mine is a failure.

The following two mining properties were not visited by the writer. The descriptions are based upon the published accounts, especially Bastin's.

The Adirondack (Graphite) Mining and Milling Company

Location. "The mill and the mine of the Adirondack . . . Company are about a mile northeast of the Champlain Graphite Company's plant, near the wagon road which skirts the South Bay shore."¹ The property was opened in 1904 but has remained idle since 1907. "The hillside quarry is about 100 by 100 feet and 30 feet in maximum depth, and all of the rock exposed is more or less graphitic." The ore is the characteristic quartz-feldspar schist, readily cleavable, "which is more uniform in character than that at the Champlain mine," probably due to the absence of faulting. "The strike is quite regular and averages N 80° W. The dip is about 30° south. A thickness of 25 feet . . . is exposed."² "The graphite forms very fine, thin scales coating the cleavage planes. It is accompanied by brown mica, garnet, quartz and pyrite."³

"A thin section of the typical ore when examined under the microscope shows quartz as the most abundant mineral with sharply bounded . . . [sericite] aggregates, which . . . represent altered feldspar grains and abundant brown biotite. Associated with the last and for the most part interleaved with it occurs the graphite, which according to an analysis made in the laboratory of the United States Geological Survey, constitutes 5.29 per cent of the rock. The sample analyzed was a composite one collected by the writer [Bastin] from various parts of the quarry and probably approaches closely the average run of the mine. Some chlorite and zoisite occur, and certain bands parallel to the schistosity are very

¹ Bastin, E. S., Mineral Resources, U. S. G. S., 1909, 2: 823.

² Bastin, E. S., *ibid.*

³ Newland, D. H., N. Y. State Mus. Bul. 102, p. 76.

rich in pyrite. The rock owes its foliated structure to subparallel arrangement of the graphite and the biotite flakes. The graphite flakes in the thin section studied vary from 0.02 millimeter to 0.015 millimeter wide and range up to 0.9 millimeter in length. The average length is not over 0.5 millimeter.

"The mill of this company was situated at the quarry, but at the time of the writer's [Bastin] visit had not been running for many years. The equipment includes a jaw crusher, crushing rolls, a stamp mill with two batteries of five stamps each, an inclined screw washer, Wilfley table, two buddles, and a flotation separator of special design."¹

Chemical analysis of the Adirondack Company's ore

SiO ₂	65.10
Al ₂ O ₃	9.15
Fe ₂ O ₃	4.68
FeO.....	3.09
MgO.....	2.21
CaO.....	1.71
Na ₂ O.....	.24
K ₂ O.....	2.32
H ₂ O —.....	.50
H ₂ O +.....	2.33
TiO ₂	.96
CO ₂	None
P ₂ O ₅	.74
S.....	3.26
MnO.....	.03
FeS.....	.....
C..... Graphite.....	5.29
Total.....	101.61
Less O.....	1.63
Total.....	99.98

Analysis by George Steiger, U. S. G. S., Bul. 591, p. 40.²

The Silver Leaf Graphite Company

"A prospect opened by the Silver Leaf Graphite Company" in 1904 "is situated in the woods about a mile west of the Champlain Company's mine. It consists of one pit 15 feet wide and 40 feet long and 5 to 6 feet deep. The ore is similar to that at the Champlain mine. The graphite schist strikes 40° west and dips 25°

¹ Bastin, E. S., Mineral Resources, U. S. G. S., 1909, 2: 823.

² F. W. Clarke gives this analysis in U. S. G. S. Bul. 591, p. 40. Bastin, Econ. Geol., 5: 141, gives the identical analysis for the American Graphite Company's ore. As it seems highly improbable that the schists of the two localities should be exactly alike, it seems very likely that some error has occurred in ascribing the analysis to both companies. As Bastin uses the value 5.29 per cent in accounts of both of these properties he is possibly unaware of the matter.

east."¹ Bastin reports that quartzite layers are present at this locality; it is quite possible that the Swede Pond quartzite is exposed above the ore.

"The company has no mill." The property is today abandoned.

The International Graphite Company

Location. This abandoned property is situated in the township of Chester, in Warren county, $3\frac{1}{2}$ miles west-northwest of Pottersville on the southern edge of the Schroon Lake sheet, just to the east of the junction of Trout and Alder brooks. It lies in a depression which represents a limestone valley.

The mine was opened prior to 1900. In 1901 the plant was enlarged, although at that time the continuous presence of pay ore had not been demonstrated.²

Workings. The workings consist of an inclined shaft sunk to 150 feet from which a drift has been driven; a vertical shaft, depth unknown; and two small prospect pits.

Geology. W. J. Miller³ has mapped the area on the quadrangle immediately to the south of the mine as Grenville limestone and interbedded gneisses. The limestone is well shown at Natural Bridge.⁴ This area can be traced into the Schroon Lake sheet to include the International Company's property. The knowledge of the stratigraphy is not so complete as would be desirable, but the essential features apparently are as follows:

The ore bed is a quartz-feldspar schist 18 to 25 feet thick dipping 25° N 50° W (magnetic). This grades into the overlying layers which contain more and more mica until a mica schist is the dominant type. Above is an amphibolite, which very likely represents an altered impure limestone formation, as will be pointed out later. Succeeding the amphibolite is a thick bed of limestone, with interbedded layers of granular, siliceous rock. This is overlain by another amphibolite. This group of rocks, above the ore, taken *en masse*, very probably is equivalent to the Faxon limestone that we have noted before. But on the International property this is a thick formation, the upper beds possibly representing a replacement of part of the Swede Pond quartzite by limestone. Succeeding this group is a quartz gneiss often with garnets and shreds of mica. It is seamed and cut by igneous injections to the extent that

¹ Bastin, E. S. Mineral Resources, U. S. G. S. 1909, 2:823.

² The Mineral Industry for 1901, p. 369.

³ Miller, W. J., New York State Mus. Bul. 170.

⁴ Loc. cit., plate I, facing p. 10.

it rarely presents a pure type of rock. The writer's interpretation is that it is in part sedimentary and in part igneous; the Laurentian granite has injected it, soaked it, and has assimilated sufficient quantities to form a syntectic rock. It is suggested that this represents the Swede Pond horizon. The presence of the Laurentian, the Algonian granite, or the siliceous and argillaceous character of the Faxon limestone may be factors in the production of the contact type of amphibolite which forms the base and top of the Faxon formation. In the field north of the mine the syntectic Swede Pond gneiss is cut by a diabase dike, $2\frac{1}{2}$ feet wide running N 60° E.

If the above relations hold, the following is especially important, not only scientifically but as bearing on the problem of the graphite resources of the State. Resting upon this syntectic rock, and forming the slopes of Catamount mountain is a sillimanite schist, which furnishes the type example of the Catamount schist (see the Bear Pond mountain region). It is believed that the full thickness of the Catamount is shown here. Certain phases are somewhat graphitic and the inference is strong that we are not far from the horizon of the Bear Pond schist, the ore-bed of the Bly property. That such is the case, however, is by no means demonstrated, but the suggestion is worth considering. If such is the case, then, there are two distinct graphitic beds. From what has been learned it is safe to say that the lower (stratigraphically), or Dixon schist, is the better of the two. Provided that the stratigraphy as here developed is actually the true state of affairs, then prospecting for more graphite takes on a new significance.

The ore. A specimen taken from the ore bin, representing the typical rock mined, was found under the microscope to be a quartz-feldspar schist, abnormally high in graphite and pyrite, the latter running 25 per cent by weight of the rock. Biotite and phlogopite, which are present in greater amounts than is usually the case, are interleaved with the graphite like leaves in a book. In addition to these differences from the normal Dixon schist the presence of diopside (a member of the pyroxene family) and tourmaline must be noted. Material from the rock dump reveals many evidences that igneous action of the pegmatitic variety has taken place in this vicinity. Contact rocks of all sorts are plentiful, although actual access to them *in situ* is impossible. The peculiar nature of the ore strongly suggests that redistribution and concentration of the graphite flake has taken place, resulting in a rich zone within the

schist. As we shall see later, the Rowland and the Sacandaga ores are very similar. The flake is comparatively large and interleaved with the pyrite and mica.

The percentage of biotite is sufficiently high to give serious difficulty to the miller, which was the case, the writer was informed. Certain specimens taken from the dump show a decided approach toward hydrothermal action, almost veiny in habit.

Quantitative microscopic analyses of the International ores

		No. 741 Ore bin typical	No. 742 Ore dump very rich	No. 739 Second prospect hole east of shaft	No. 745 Concentrate
APPROXIMATE COMPOSITION BY WEIGHT	Graphite.....	7.1	.....	4.5	.....
	Biotite.....	5.7	.....	trace	.....
	Chlorite.....	trace	.....	trace	.....
	Andesine-labradorite.....	20.6	.....	50.0	.....
	Quartz.....	38.8	.....	2.0	.....
	Pyrite.....	22.1	.....	2.3	.....
	Apatite.....	1.1	.....	.2	.....
	Diopside.....	3.4	.....	22.0	.....
	Tourmaline.....	2.2	.....	none	.....
	Hornblende.....	none	.....	19.0	.....
	TOTAL.....	100.0	.....	100.0	.....
SIZE OF THE GRAPHITE FLAKES	DIAMETER IN HAND SPECIMEN	Average.....	1.04 mm	1.68 mm	.53 mm
		x	1.61 mm	2.50 mm	.77 mm
		Maximum.....	2.40 mm	5.20 mm	1.50 mm
		Minimum.....	.50 mm	.85 mm	.30 mm
	LENGTH IN THIN SECTION	Average.....	1.03 mm	.43 mm	.....
		Maximum.....	1.70 mm	.90 mm	.....
		Minimum.....	.40 mm	.20 mm	.....
	THICKNESS IN THIN SECTION	Average.....	.042 mm	.033 mm	.....
		Maximum.....	.080 mm	.055 mm	.....
		Minimum.....	.025 mm	.018 mm	.....

The igneous activity has brought about a rich ore, specimens of which can be found that are far richer than the usual Dixon or Bear Pond schists, but the improvement in the amount of graphite is obtained at the expense of uniformity. This element in graphite milling is an important factor and is frequently overlooked. It is not difficult for the writer to appreciate this cause in the failure of the company.

Faults. In the bed of Alder brook, at the bridge just before reaching the mill, the pink Algonian granite is splendidly shown in

its typical development. Consulting the geological map of the North Creek quadrangle we find that Miller has indicated a fault extending from a point a mile northeast of Holcombville northeast to the edge of the sheet. He says:¹ it extends "along the western base of the Henderson mountain mass. Its position is plainly marked by the topography, and though the scarp is not as steep as usual, it is nevertheless very prominent and straight and cuts across the foliation of the rocks at a high angle. . . . As judged by the height of the scarp at the south end and also at the base of Henderson mountain, the displacement is fully 700 feet. . . . No tilting of this fault block is noticeable. This fault certainly continues for some 3 miles northward into the Schroon Lake quadrangle along the western bases of Green and Pine Hills." The writer's observations are in perfect accord with this interpretation. This fault, which brings in the granite, delimits the graphite ore on the west. Several prospect pits to the east of the mine show graphite, but the rock actually exposed is the micaceous schist—the upper transition beds of the ore. How far the graphitic schist can be traced eastward along the strike is not known, but it is quite reasonable to expect that it can be done for some distance.

Mining and milling methods. The main inclined shaft is completely housed and leads directly from the floor of the hoisting shed downward for 150 feet with a steep angle, at which level a little drifting has been done. From the hoisting house the ore was trammed in small cars through a covered passageway to the ore bin and drying house. Crushing, stamping, buddling and screening were the essential features of the process.

Economic conditions at this property are not very favorable for production. Mining operations are down to creek level, forcing the employment of pumps every inch of the way. The ore, although exceedingly rich in spots is very variable, due to the igneous (magmatic) agencies of the Algonian granite. The latter rock exists near the surface beneath the ore which probably limits the schist as to depth. The high biotite-phlogopite content and toughness are factors also to be considered.

The Rowland Graphite Company

Situation. The property is in the township of Johnsburg, Warren county, about a mile south-southwest of the village of Johnsburg and 6 miles by an excellent state road southwest of Riverside station

¹ Loc. cit., p. 56.

on the Adirondack division of the Delaware and Hudson Railroad within the North Creek quadrangle. The exact location is shown by the crossed hammers on the geological map of the North Creek sheet.¹ The mine is situated on the southern slope of a low hill.

The Rowland property, in fee and lease, covers over 200 acres in the valley of Mill creek.²

Beck,³ in 1842, wrote: "In Warren county, graphite will probably be found in considerable abundance. There is a locality of it on the farm of Mr Noble, at Johnsburg. Several hundred weight of good graphite has been obtained from this mine. The mineral occurs in irregular shaped masses weighing from one to twenty pounds, in a vein of quartz."

Active development of the property took place prior to 1899. In 1900 operations began and working continued as late as June 1910, but today the mine is idle. There seems to be no prospect of reopening the mine.

Workings. "The principal opening consists of an open cut running westerly [N 72° E, magnetic] . . . about 100 feet long and 30 feet deep at the west end, where a shaft in the deep west end of the cut penetrates the bed of graphite schist to a depth of 22 feet below the present bottom of the cut, and a short drift running southward from the shaft on the richest part of the bed."⁴

Geology. The immediate area has been mapped by W. J. Miller as composed of Grenville crystalline limestone interbedded with hornblende and hornblende-garnet gneisses, which strike N 70° E and dip 20 to 35° to the south.

The ore bed is in all probability the Dixon schist, some 28 feet in thickness, the upper portion of which is decidedly micaceous and lean in graphite while the center is exceedingly rich due to igneous redistribution and reorganization, as will be shown later. Associated with the ore is a limestone (the Faxon), in part interbedded with it and in part beneath, specimens of which may be obtained from the material removed from the entrance of the trench. Above the ore is a quartzite, just what the reader may expect, the Swede Pond formation; on top of this is a hornblende-biotite rock that occurs as an isolated patch in the field to the southwest of the mill.

Beneath the ore is another quartzite, about 50 feet thick, which the writer regards as equivalent to the Hague gneiss. This is void

¹ Miller, W. J., N. Y. State Mus. Bul. 170.

² Information kindly furnished by Mr Charles T. Rowland.

³ Beck, Nat. Hist. of N. Y. State, pt. 3 Mineralogy, 1842, p. 421.

⁴ Crosby, W. O., Special report on the property.

of garnets and the particular slide examined failed to show any sillimanite. Whenever the Laurentian granite is found its habit invariably is to saturate, to soak into, and inject a quartzose formation and leave the more calcareous and ferruginous beds unaffected. The Hague gneiss, except for the minerals that furnish the customary earmarks, is essentially a feldspathic quartzite. Garnet and sillimanite are regarded by most petrographers as indicating or strongly suggesting metamorphic action. The writer would therefore maintain that these two minerals are not reliable or consistent characteristics of this formation but may be due to the Laurentian granite which is absent at the Rowland property. This Hague quartzite is decidedly purer than its equivalent at Hague.

At the Hooper property we saw that a para-amphibolite stratigraphically lies beneath the Hague gneiss. This was tentatively named the Dresden. Its presence on the Rowland property at this horizon fits in with the general scheme of things. This amphibolite is about 65 feet thick, which is exposed on the western slopes on the knob to the northwest of the mine. Below the para-amphibolite is a limestone formation which we have not before encountered. This I propose to call the Johnsburg limestone, of which only the top portion was seen, so the total thickness is unknown.

The Algomian granite is exposed at the village of Johnsburg, but lies at no great depth under the sedimentary rocks, up through which it has sent numerous pegmatites and profoundly affected the Dixon schist.

Structure. The knowledge of the succession of the beds was applied to the problem of the structure. The mill is situated in a low depression between two low hills, the one to the north being of some prominence. The latter is composed almost entirely of the Hague quartzite dipping south. Although the summit of the hill is higher than the mine, it represents a horizon stratigraphically beneath the ore; hence the Dixon schist has been eroded and no ore to the north of the shaft in the immediate vicinity can be expected. This hill is an anticline, while the low dome to the south of the hill is a syncline in a north and south section which in reality is a structural basin, with its major diameter probably lying in an east and west direction. The actual extent to the east is not definitely known. The accompanying reconnaissance map perhaps brings out this idea better than a description. The semicircular swing of the graphitic schist is entirely inferred from the occurrence and behavior of the Swede Pond and the Hague quartzites, as well

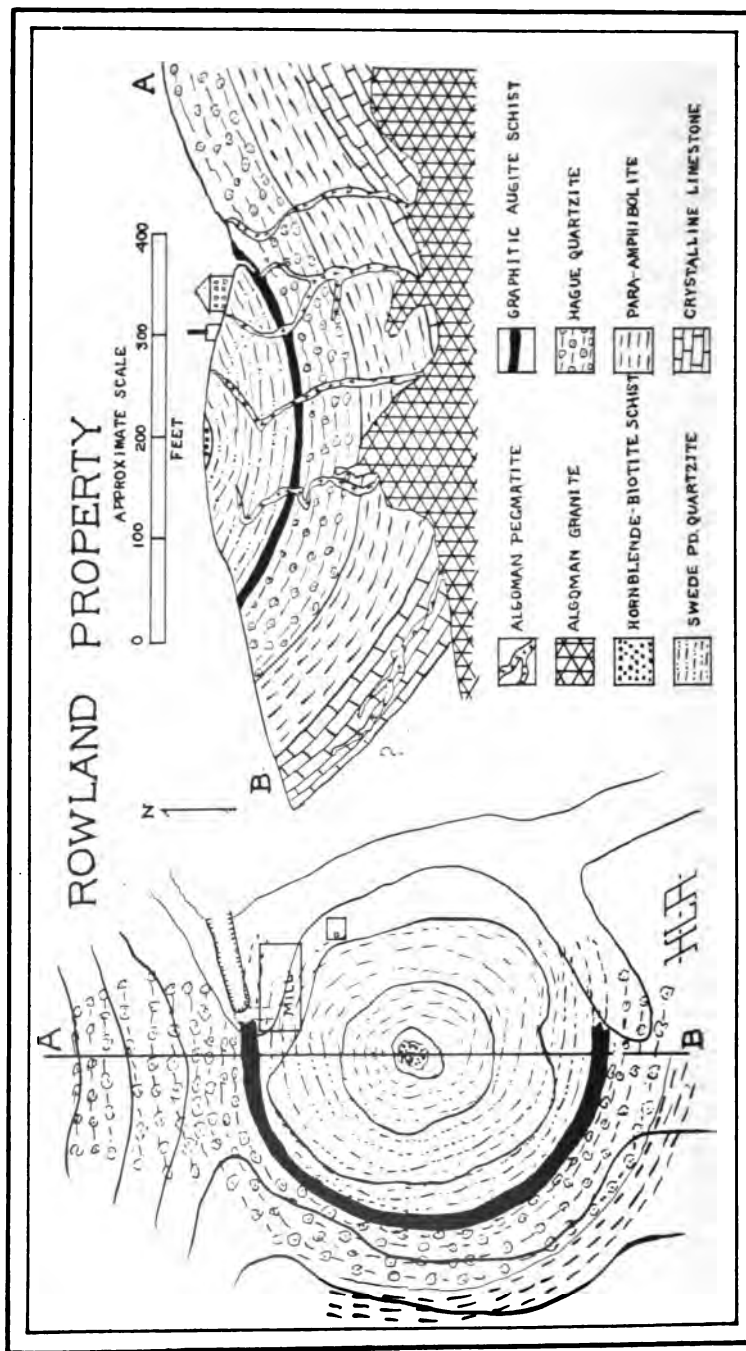


Fig. 18 Geologic reconnaissance map and north-south section of the Rowland property. The Grenville rocks, including the ore, have been folding in a structural basin. The Faxon limestone, which normally lies upon and in the graphitic schist is omitted, as its position and thickness are not perfectly known. G. H. Chadwick and H. L. Alling, 1917.

as the Dresden amphibolite. Although the map is based upon measurements secured by pacing, it is quite clear that the diameter of the basin is not over 300 to 500 feet. If this is so, then the amount of ore present on this property is decidedly limited.

Amount of ore. The mine is located upon the rim of the structural basin. Professor Crosby, in a report upon the property, remarks that the dip seems to flatten as the drifting to the south continues. This is exactly what would be expected from such a structure. Toward the center of the basin the dip should approach zero.

All the rocks in the neighborhood are shot through by pegmatites in such a manner as to indicate that the Algonian granite is not far distant. It is a possibility that it has cut off the ore bed near the center of the basin. Some exploratory work in the way of trenching along the line represented upon the map would be advisable. Several well-placed diamond drill holes would settle many of the questions raised.

Let us calculate the probable amount of the ore, assuming that the above inferences are facts.

Appropriate diameter of basin, 400 feet.

Area of basin, 125,600 square feet.

Thickness of pay ore, 10 feet.

Volume of pay ore, 1,256,000 cubic feet.

Weight of one cubic foot, 168 pounds.

Weight of pay ore, 210,000,000 pounds.

Amount of available graphite, 5 per cent.

Weight of graphite in ore, 10,500,000 pounds or 5250 tons.

This, of course, assumes that not much ore exists to the east. It is not certain how far it continues. In walking east from the mine toward the fork in the road ("1355" in altitude), in the first brook crossed, the Johnsburg limestone was found beneath the Dresden amphibolite. Furthermore, W. J. Miller has placed a little cross (X) upon the geologic map where the secondary road crosses this same stream. This indicates limestone. The writer does not know whether it is the Johnsburg or the Faxon, but it is more probable that it is the former. The ore certainly does not reach this far. This perhaps illustrates the practical side of applied geology.

The ore. The bedded ore of the Rowland property reminds us of that found at the International Company's mine. It has been affected by the Algonian granite. Below is the tabulated result of

microscopic analyses, percentage by weight. It is at once apparent that there is a very great range in the ore. The bed sufficiently graphitic to be regarded as ore is something like 25 feet thick, of which one-third appears to be a good workable ore. Crosby had representative samples collected at intervals of 1 foot from two parallel sections 10 feet apart, through the richest part of the bed. He classifies the bed as follows:

"1 Eight feet of micaceous quartzite with more or less graphite, chiefly in streaks and affording some graphitic ore.

"2 Twelve feet of graphite schist, probably all of workable grade and much of it carrying 10 per cent or more of graphite.

"3 Ten feet of quartzite and brown mica schist with some disseminated graphite and streaks of graphitic schist.

"A general or composite grab sample of fifty pieces from the pile of ore from the drift . . . was analyzed by Dr W. T. Hall of the Massachusetts Institute of Technology with the following result: 8.09 per cent of graphitic carbon. This is certainly a very favorable showing . . . and it is equally certain that a considerable part of the Johnsbury bed runs over 10 per cent of graphite and some of it over 20 per cent."¹

¹ Quoted from Professor Crosby's report.

Quantitative microscopic analyses of the Rowland ores

			No. 734 Ore bin typical	No. 731 Base of outcrop in the trench	No. 732 Five feet higher than 731	CONCENTRATES	
						No. 736a ¹	No. 736b ²
APPROXIMATE COMPOSITION BY WEIGHT	Graphite.....		9.4	6.5	2.1		
	Biotite.....		trace	1.0	20.3		
	Chlorite.....		1.5	trace	trace		
	Andesine-labradorite.....		none	25.5	36.7		
	Quartz.....		none	46.0	none		
	Apatite.....		trace	trace	trace		
	Diopside.....		84.7	14.5	3.7		
	Titanite.....		trace	2.0	3.3		
	Orthoclase.....		none	trace	10.5		
	Tourmaline.....		none	none	2.2		
	Zircon.....		none	none	.1		
	Pyrite.....		1.5	4.5	21.1		
	TOTAL.....		100.0	100.0	100.0		
SIZE OF THE GRAPHITE FLAKES	DIAMETER IN HAND SPECIMEN	Average.....	1.22x.89 mm	1.00x.54 mm	.67x.52 mm	1.05x.61 mm	.70x.46 mm
		Maximum.....	2.40 mm	1.90 mm	2.25 mm	2.10 mm	1.20 mm
		Minimum.....	.40 mm	.27 mm	.31 mm	.30 mm	.27 mm
	LENGTH IN THIN SECTION	Average.....	1.03 mm	.68 mm	.51 mm		
		Maximum.....	1.70 mm	1.10 mm	.90 mm		
		Minimum.....	.60 mm	.40 mm	.25 mm		
	THICKNESS IN THIN SECTION	Average.....	.067 mm	.050 mm	.034 mm		
		Maximum.....	.130 mm	.100 mm	.080 mm		
		Minimum.....	.025 mm	.010 mm	.018 mm		

¹Chemical analysis by H. F. Gardner gives 85.04 per cent graphitic carbon.²Chemical analysis by H. F. Gardner gives 54 per cent graphitic carbon.

Such a rich ore is not the usual experience in the bedded deposits of the Adirondacks. Whenever a rich type is encountered, such as at the International, the Rowland and, as we shall see, at the abandoned Sacandaga mine, igneous agencies have left their mark. Pegmatitic action has moved some of the original carbon in the schist from one layer to another. White pyroxenes, usually diopside, have been developed partly from original primary constituents and partly from introduced magmatic matters. Here at the Johnsbury locality the ore from the center of the bed is exceedingly abundant in diopside (84.7 per cent by weight for specimen 734). This makes a rock very difficult to crush without severe attrition of the flake. Thus there are disadvantages in a rich ore. Furthermore, it makes a variable bed that at once presents special concentration problems.

Vein type of graphite. Quite distinct from the bedded deposit is the occurrence of several true fissure veins of quartz carrying foliated graphite. They without doubt represent the last dying phases of the igneous activity of the Algonian granite. These veins are chiefly of hydrothermal deposited quartz that cut through the schists and quartzites in a most irregular way. Bordering the edges of these veins of pure milky quartz, the fibrous graphite is arranged in rosettes and spherulitic forms as a fringe, often an inch in width. One of them cuts diagonally across the trench so that it is exposed on both sides. A detailed drawing of this par-

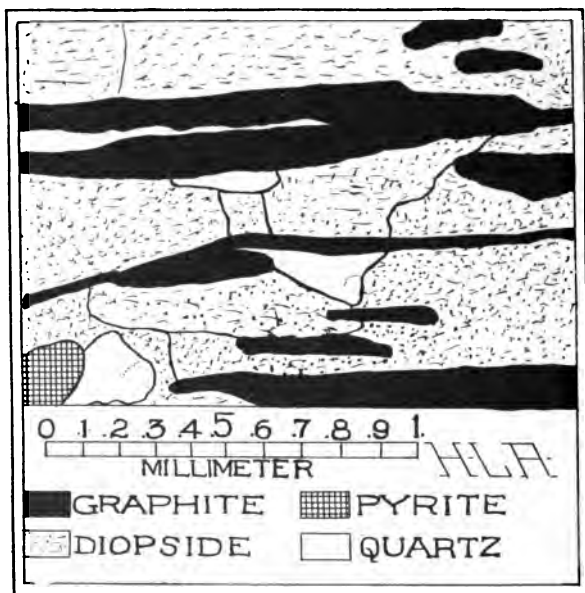


Fig. 19 Camera-lucida drawing of microscopic thin section of the "high-grade" Rowland ore, showing the graphite flakes embedded in diopside. H. L. Alling, 1918.

ticular one is here given. It has been stated that two more veins were found in the shaft and drift. "The mine superintendent stated that in 1899 one piece of nearly pure graphite weighing 543 pounds was taken out."¹

Exceedingly attractive specimens may be collected from the dump; they are so striking that it is not surprising that they have

¹ Miller, W. J., N. Y. State Mus. Bul. 170, p. 82. A chemical analysis by H. F. Gardner gives 82.72 per cent graphite carbon for the vein type of graphite.

aroused serious interest. While individual masses of this fibrous graphite seem to compare very favorably with certain grades of Ceylon graphite, its limited and erratic habit prohibit any serious consideration as a source of graphite.

Here we have a very instructive display of graphite in three associations. In the first place, the sedimentary schist with its 5 to 6 per cent of graphite; second, the highly concentrated center due to a mild form of contact metamorphism; and third, true fissure fillings of quartz with fringes of graphite. The writer wishes that

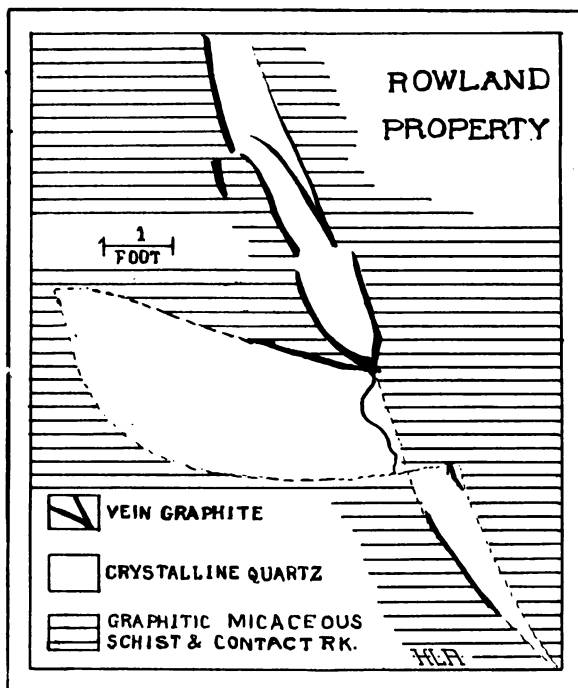


Fig. 20 Detailed drawing of a true fissure vein carrying graphite on the Rowland property. This is situated on the south side of the trench 40 feet from the portal of the shaft. G. H. Chadwick and H. L. Alling, 1917.

graphite men could see this type with its peculiar and characteristic habit and make the easy distinction between the different occurrences. One of the purposes of this bulletin is to suggest a rational way of sizing up a graphite property. If the mode of origin is appreciated, much worry is dispensed with. The distinction between the different types is usually not difficult; here, at the Rowland mine, it is possible to see the behavior of bedded ores and veins and comprehend the relative values.

The first mill was constructed on piles on the bank of Mill creek; the selection of this site was unfortunate for the first spring flood carried it downstream. The present mill stands upon the rim of the basin forcing the company to hoist the ore 50 to 60 feet by a cranellike arrangement into the ore bin. Pumping is necessary to keep the shaft and drift dry. It is possible that such an expensive method could have been avoided by placing the mill farther to the east and driving a horizontal drift following the strike.

It was observed that the mill was not arranged so that a complete gravity system could be employed. For example; the top of the crusher hopper was not flush with the floor of the ore bin. This necessitated the rehandling and lifting of the ore.

Water in the vicinity is plentiful, especially to the west in Mill creek where a small dam was built and water pumped over the brow of the hill to the mill, evidently for the boilers. Yet the dry method of concentration was attempted. A Newaygo separator, manufactured by the Newaygo Portland Cement Company, was employed. This proved unsatisfactory, but recently experiments with an electrostatic process were made with excellent results, it is stated.

The transportation facilities are very favorable. A comparatively new state road runs from Riverside, the nearest railroad station to Weaverton (Weverton on the map), from which there is a fairly good dirt road to Johnsbury. It is understood that the construction of a road $1\frac{1}{4}$ miles in length would make transportation a simple matter for motor trucks.

Summary. It has been shown that the amount of ore is probably limited, variable and difficult to crush. Hence, unless a careful survey points to the contrary, we can conclude that the future of this property is rather uncertain.

The Sacandaga Graphite Company

Situation. This property is in the township of Day, Saratoga county, $1\frac{1}{4}$ miles due west of Conklingville in the Sacandaga valley, within the Luzerne topographic sheet. The property may be reached by an 8 mile drive from Hadley, on the Delaware and Hudson Railroad, following the north road west of Conklingville to the fork (with a bench mark of 748 feet) and turning north along the east bank of a small stream, three-eighths of a mile. The mill stands to the west of the road. The mine is located about 1700 feet to the east at an elevation of 1000 feet,

The property was opened in 1906 by the Glen Falls Graphite Company. In 1911 the Sacandaga Graphite Company took over the mine and mill. The mill was constructed in 1906.¹ Today the property is abandoned.

Openings. There are three irregular-shaped open pits dug into the southwest slope of a prominent knoll. The southernmost one is a wedge-shaped pit excavated between the converging footwall which forms a V in vertical section. The middle pit is verging upon a drift. The third opening is a long trench, now partly filled with water dug along one of the walls of the V.

Geology and structure. The rocks found in the Sacandaga mine are dipping about 30° N 20° E into the hill slope. They are crushed, sheared and affected by igneous agencies to such an extent that the unravelling of the geological structure is apparently a difficult matter. When the stratigraphy of the beds is worked out in detail, however, it is evident that we are dealing with a syncline, tightly squeezed, and strongly pitching to the northwest.

The graphite schist is very probably the familiar Dixon schist. Its normal thickness has been greatly reduced so that 10 feet was the maximum thickness observed, the average being about 5 feet. At one spot the top layers grade into a narrow band of quartzite, comparatively free from graphite, but this is immediately succeeded by a bed of mica schist. Stratigraphically on top is the familiar limestone, referred to as the Faxon. This is never present in its full thickness and is often wanting in a given section; it has been squeezed and pulled apart during the intense folding. Overlying the limestone is a quartzite, heavily injected by the Laurentian granite which has developed a high percentage of feldspar (now entirely altered to sericite) and biotite. This is without doubt the Swede Pond quartzite soaked by the old granite. The type example of this is the syntectic gneiss shown on the Hooper property. The rock here does not exhibit its full thickness as the upper portion has been cut off and replaced by the Laurentian granite. The latter rock is exposed at two places near the pits; to the southwest of the middle pit and the trench, where it has been crushed to a pulp resembling the anorthosite of the east central Adirondacks. Above the Laurentian is a black rock, very hard to break, containing flakes of muscovite mica. It was classified in the field as a metagabbro. An examination of a slide cut from a hand specimen, however, casts serious doubt upon such an interpretation. This is composed almost

¹ Newland, D. H., N. Y. State Mus. Bul. 112, p. 27.

entirely of augite and scapolite with brilliant green spinel and brown tourmaline. It is a contact rock. It seems to cut irregularly across the bedding of the sedimentary rocks. It seems likely that the Algonian granite was in part, at least, responsible for its development.

The series of rocks that underlies the ore is unusually complete. Directly beneath is the Hague gneiss, which forms the walls of the wedge-shaped pit. It is not quite like the typical rock as exposed at Hague, for instead of sillimanite, the rock contains biotite. Below is the para-amphibolite (the Dresden), followed by the limestone that occurs at the Rowland property. This is the Johnsburg limestone of the writer. It has suffered shearing and stretching in a manner similar to that experienced by the Faxon. It is found only here and there. Up to this point in the description of the graphite properties, beds lower down in the geologic column have not been encountered, but the Sacandaga mine furnishes a new bed. This is another quartzite that will be termed the Sacandaga quartzite. The thickness of this formation is unknown.

The structure of the beds has already been outlined; a syncline whose axis lies in a northwest-southeast direction, pitching to the northwest, has been truncated by erosion so that the present surface of the hill slope cuts diagonally across the beds, which outcrop in the form of a V with the apex to the southeast. In vertical section this gives a V inclined 30° into the hill slope. The accompanying block diagram is an attempt to present this a little more concretely. The southern pit is located at the very apex of the fold. When the pit was abandoned, the miners had worked out all the ore, inasmuch as they encountered the Hague gneiss on three sides.

The other two pits are located upon the northeast limb of the fold. The miners confined their operations to the single outcrop. They have not followed down the dip of this limb far enough to reach the bottom of the fold, but it is evident that at the pits the amount of ore is exceedingly limited. It is possible that more ore could be found farther along the strike to the northwest.

Sedimentary type of ore. The ore that has received serious attention is very probably the Dixon schist, but the Sacandaga exposure shows a decided variation from the usual type. It is a feldspar schist, very low in quartz but high in graphite, the latter running about 10 per cent in the central zone of the bed. The feldspar is chiefly microcline-micropertthite, comparatively fresh, while the subordinate introduced (3) oligoclase-andesine is almost completely altered to sericite. There are two micaceous minerals

present; one is brown biotite (perhaps the variety known as haughtonite), while the other is a pale yellow-green mica approaching chloritic or chloritoid forms. (The latter may be ottrelite in part.) Pyrite is present but a little lower in amount than is usually the case. The richness of the ore and its high potash (microcline) content point to igneous activity similar to that displayed at the

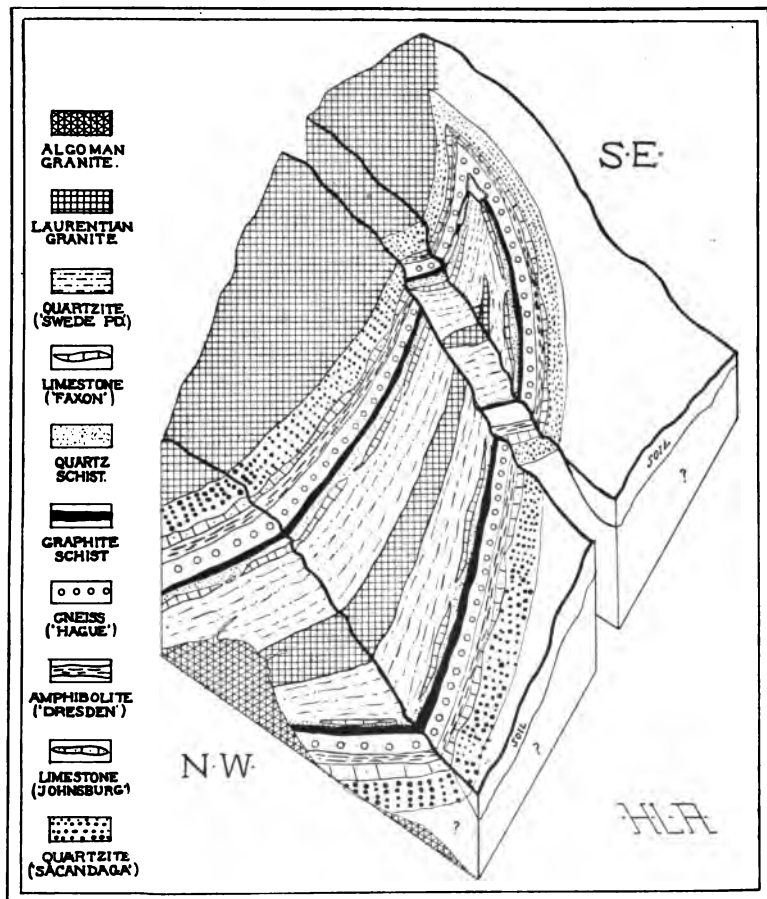


Fig. 21 Generalized block diagram of the Sacandaga Graphite Company's property, showing the inclined pitching syncline, invaded by both the Laurentian and the Algonman granites. The three pits are indicated near the apex of the fold. Length of the block is about one-fourth of a mile. Structure by G. H. Chadwick. Geology by H. L. Alling, 1917.

International and Rowland mines. The graphite appears to have been reorganized and redistributed, developing a very rich zone. The graphite flakes are not confined to the schist, as the adjacent rocks contain scattering amounts.

Microscopic analyses and size of the flakes

	Middle Pit + Central Zone	Length of flake	
	No. 829	Average.....	.72 mm
Graphite.....	10.5	Maximum.....	1.40 mm
Biotite.....	5.5	Minimum.....	.32 mm
Chlorite.....	5.5	Thickness of flake	
Microcline-micropertite.....	67.5	Average.....	.042 mm
Oligoclase-andesine.....	5.0	Maximum.....	.098 mm
Quartz.....	2.0	Minimum.....	.020 mm
Pyrite.....	2.0		
Apatite.....	2.0		
TOTAL.....	100.0		

Contact type of ore. The igneous, or pneumatigneous, action attributed to the Algonian granite is further shown by the development of the contact type of graphite. It was found in small amounts in the trench and in the middle pit. The rock that carries the large flake is the usual pyroxene material—the type gangue of the graphite of the northern area.

Whether or not the richness of the graphite now found in the sedimentary schist is in any way due to the infiltration of any of the contact type is an unsettled question, but the suggestion is worthy of consideration.

Summing up all the facts and relationships observed, it is very clear that folding, redistribution and igneous agencies have all had a share in the development of the mineral. It is quite certain that the sedimentary type of ore is limited, that it varies in composition and character from place to place, and is too high in biotite, as well as too difficult to crush, to arouse any commercial interest. In regard to the contact type of ore, the conclusions reached from the study of the deposits of the northern area apply here and incline us to abandon any hope that this mine will ever be productive.

The mill. The company's mill is located 1700 feet to the southwest of the mine connected by a wagon road down which the ore was teamed. A small dam has been built across the stream so that the mill was operated in part by water power. The dryers were supplied with steam from a boiler using cord wood and sawmill refuse for fuel. "Only test runs have been made with the graphite from the mine, but the power was partially utilized for very fine grinding of Ceylon graphite for electrotyping purposes." The equipment included a "Sturdevant crusher, Sturdevant rolls, hexagonal revolving screens, wet screens, a dryer of special pattern, burrstone mill, and equipment for bolting and grading."¹

¹ Bastin, E. S., Mineral Resources, U. S. G. S., 1904, 2:212.

In 1912 the following grades were made.

GRADE	PER CENT OF GRAPHITE	PRICE PER POUND
Pulverized flake.....	92	15 cents
No. 1 flake.....	90	9 cents
Stove-polish grade.....	80	6 cents
Foundry facings.....	60	3½ cents

The Flake Graphite Company

(Formerly the Empire Graphite Company)

This mining district is in the township of Greenfield, Saratoga county, $2\frac{1}{4}$ miles west of Porter Corners, just west of the Hoffmans fault. The location is indicated by crossed hammers on the geological map of the Saratoga quadrangle.¹

Workings. The principal working is an open cut extending east and west along the northern slope of a spur of the main ridge. "The outcrop of the beds strike nearly east and west and is marked by a slight depression in the easterly sloping ridge. [The graphitic schist] is traceable for 1500 feet or more from the present mine openings, which are on the eastern end of the outcrop."² From this open cut three inclined slopes have been driven following the dip of the graphitic bed into the hill. The main slope has an initial dip of 32° due magnetic south, which increases until a dip of 48° is found at a distance of 207 feet from the portal. At this depth cross cuts lead to the bottom of two parallel back stopes. At the distance of 30 feet from the present bottom another back stope has been driven from the east wall of the slope. About 50 feet from the portal one of the parallel slopes curves and joins it. Several drifts farther east that were driven by the Empire Company will be abandoned by the Flake concern.

The present inclined drift has a defective hanging wall for 50 feet or so that allows a large amount of seepage, causing a wet mine. The first few feet present a solid roof but this gives way to porous and fractured rock with some loose gravel. This necessitates timbering and the employment of tin gutters. It was found that a stream formerly had its course on the hill slope above the drift.

¹ Cushing, H. P., & Ruedemann, R., N. Y. State Mus. Bul. 169.

² Newland, D. H., N. Y. State Mus. Bul. 161, p. 34.

The stream cut into the rocks overlying the ore and effectively weakened the hanging wall. The channel is now filled with glacial material. It would have been better to have driven a horizontal drift at a lower level until the ore bed was reached and then have followed down the dip. The present methods necessitate pumping and hoisting.

In 1912 a nearly horizontal drift, then designated as "No. 2," followed the strike of the schist farther to the east than the inclines above mentioned. It was planned to block out the ore between this and the surface, but as the turn from the direction of dip to that of the strike was made too near the portal, there was little ore to be had.

Still farther east, in loose ground, a drift was attempted. This was to furnish drainage for the "No. 2" drift but was poorly planned and probably will be abandoned.

On the south side of the knoll there are three abandoned prospect holes.

Geology and structure. The area in which the mine is located has been mapped by Cushing, who suggests that the block in which the graphite-schist is found on the property, represents a portion of the same block in which similar beds occur that are now being worked by the Graphite Products Corporation, 8 miles to the east.

The Grenville rocks are dipping from 30° to 50° southward, varying from a few degrees west of south to $S\ 70^{\circ}\ W$. Cushing is of the opinion that there are two beds of the schist that "are capable of utilization, because of the high graphite and low mica content. The upper bed, from 10 to 14 feet thick, has been the one chiefly worked up to date. The lower bed is much thinner (4 to 5 feet). They are separated by a 4-foot thickness of quartzite and thin limestone. Underneath is a much more solid bed of mica gneiss."¹

The writer would question whether this parting is sufficiently well defined to separate the ore into two distinct seams. The parting consists of limestone and green quartzite layers that pinch and swell, disappear and come in again in a most irregular way. Some of the siliceous stringers are interpreted as metapegmatites of the Laurentian granite. The present miners are operating the total thickness of the rock.

The graphite rock is at present correlated with the Dixon and the limestone, which is usually siliceous, as the Faxon. The footwall was not observed at any near-by locality but the "mica gneiss" of

¹ Cushing, H. P., N. Y. State Mus. Bul. 169, p. 149.

Cushing is, in all probability, the Hague gneiss, somewhat more biotitic than is customary. Above the Faxon is the expected Swede Pond quartzite which "is more or less involved with the white, garnet-bearing granite which we regard as Laurentian."¹ This is the familiar syntectic Swede Pond gneiss. On climbing the hill this syntectic rock was observed to be penetrated by pegmatitic dikes suggesting the near presence of the Algonian granite. Thus, when the higher slopes and the summit were reached, it was not surprising to find a splendid display of the granite. This was dark grey-green in color suggesting the augite-syenite of the central Adirondacks. The microscope, however, shows the quartz content to be about 30 per cent, placing the rock among the granites. The ferromagnesian minerals are all altered to serpentine and chlorite, but probably were originally amphiboles.

The significant fact for us is that this is the Algonian and not the Laurentian granite. The latter rock was injected into the Grenville before that series was folded, and thus it frequently behaves like a stratigraphic unit, not interfering with the continuance of the ore in depth. On the other hand, the Algonian came in after the intense folding and its habit is to cut through the sedimentary layers, which include the ore. Thus the writer strongly suspects that the ore does not continue "all the way to China." How much farther down the dip the workings can continue before encountering the main body of the granite is, of course, not known, but a diamond drill would settle the matter.

On the summit of the knoll several small patches of the black metagabbro were observed that remind us of the Hooper property. On the farther side of the same hill a large mass of it was found cut by the Algonian but cutting the Laurentian injected Swede Pond gneiss, thus establishing their relative age relations. That all the metagabbro of the Adirondacks is of the same age is certainly not proved. Doctor Cushing says that "there is certainly much (ortho-)amphibolite in the region which is older than the Laurentian and is the oldest eruptive present, so far as I know,"² There seems to be no escape from the fact that this metagabbro, on the property, is younger than the Laurentian granite but older than the Algonian granite.

Passing over the metagabbro, an outcrop of the Swede Pond gneiss was again found. At one spot a minor fault was suspected by the brecciated condition of the rock. This gneiss is succeeded

¹ Ibid.

² Communicated by letter, November 1917.

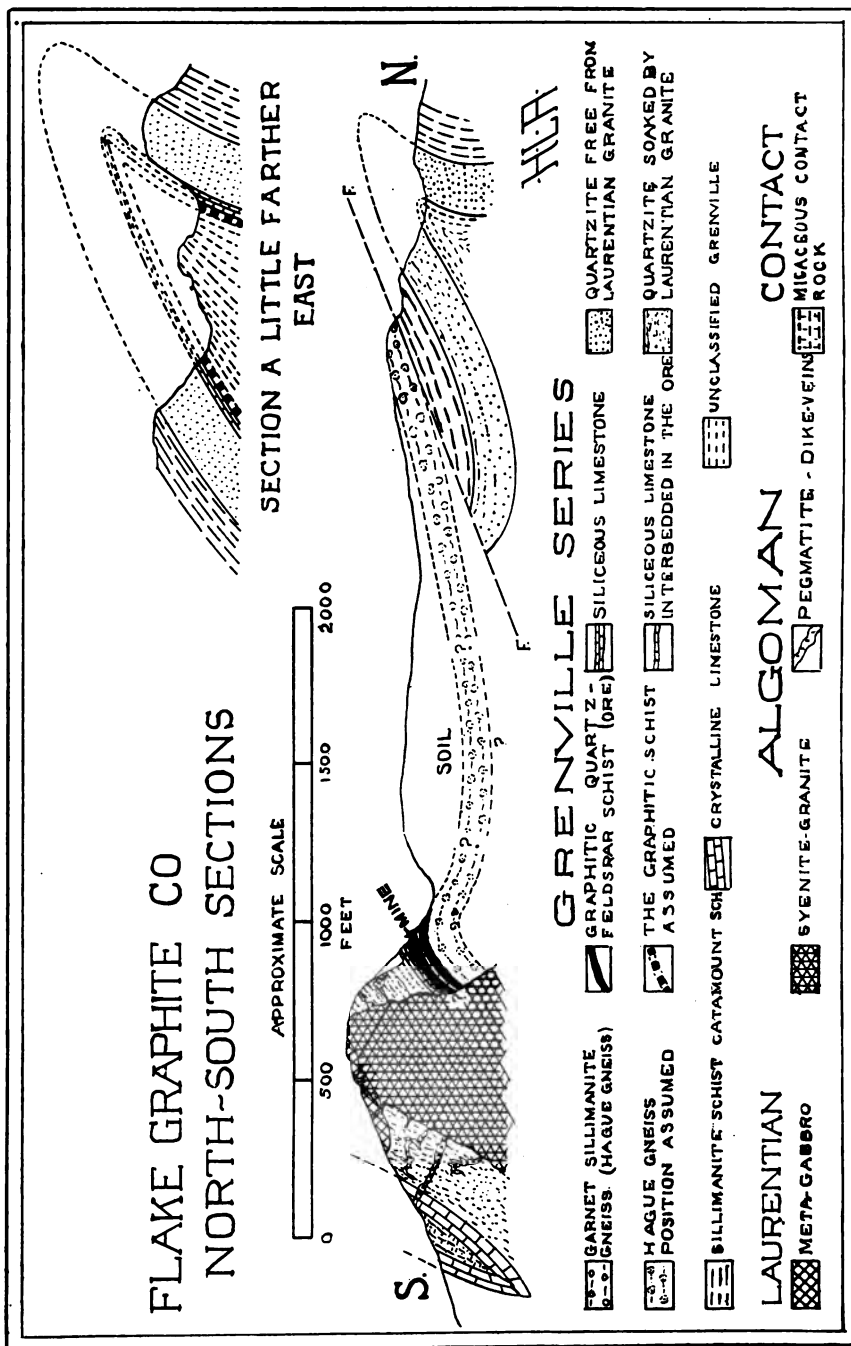


Fig. 22 Geologic reconnaissance cross-section of the Flake Graphite Company's property. Based upon a traverse by G. H. Chubbick and H. L. Alling, 1917.

by a bed of limestone which is correlated with the crumbly limestone which we met with on the Faxon property. Continuing southward, ignoring the numerous pegmatites, a biotitic rock was found that has been unsatisfactorily interpreted. Some of it is clearly a contact rock consisting of titanite and biotite, while other specimens are quartz-augite rocks with chondrodite (?); still others look like the Hague gneiss, but its presence here would be difficult to explain unless there has been a repetition of the beds by faulting or that this limestone is the Faxon rather than the crumbly member. The limestone is again found near the base of the hill, probably repeated by isoclinal folding.

In this limestone occur two prospect pits of bygone days. One of them was of the nature of a drift driven into the hillside in a crush zone, along which pegmatitic solutions have given rise to a limited amount of the contact type of graphite. At a later geologic period a narrow diabase dike 34 inches wide, N 60° E, has followed the same line of weakness.

The second pit is located a little distance farther up the slope and a little to the west. Here a trench was made in serpentinized limestone that is today verde antique marble. This is in contact with a mass of the perplexing "biotitic rock." One of the pegmatites above mentioned has cut the limestone and developed a good display of the spectacular contact type of graphite. The third pit is a square shaft sunk some 10 to 12 feet in barren pegmatite.

Outcrops are lacking immediately north of the mine; the nearest exposures occur perhaps three-eighths of a mile distant on the farm owned by Nathan Towne. The typical Hague gneiss dipping 20° S 0° E was found cut by numerous pegmatite dikes, which in one place have developed graphite by contact action. Beyond a gap of 20 feet is an exposure of the typical Catamount schist, so similar to the rock from the Bear Pond mountain region that hand specimens of the two are indistinguishable. The Catamount here dips 51° S 2° E. In the glacially filled depression between the two rocks Mr Towne dug up for us a few pieces of graphitic schist. It would seem to us that that ore was a transported boulder, not in place.

Continuing northward the thick Swede Pond quartzite was encountered. The writer followed the road, passed over a gap and found the quartzite again forming a precipitous cliff. The Swede Pond here was a beautiful semitransparent to translucent pinkish buff rock, dipping 50° magnetic south. Beyond, the Catamount reappears. The interpretation that the writer would put upon these

relationships is that the Catamount schist and the Swede Pond quartzite are anticlinally folded, while the Hague gneiss has been overthrust upon the Catamount; the little valley, in which the stray ore was buried, representing the fault line depression. Retracing his steps to the gap between the exposures of the Swede Pond and swinging to the east along the base of the cliff, the writer found a rusty micaceous schist filling the core of the anticline. Identification of this rock is rendered impossible, due to the fact that it is badly weathered, sheared and fractured.

The tentative vertical section (see figure 22) which is based in large measure upon Professor Chadwick's suggestions, indicates that the rocks are folded, faulted and penetrated by igneous rocks in a complicated manner. The stratigraphy as here disclosed is apparently identical with that shown on the Dixon and Faxon properties. The structure, however, is far different, rendering the mining conditions less favorable.

The ore. The graphitic schist is in many respects similar to the Dixon, Faxon, Hague and Hooper ores. There is, however, considerable variation, which is shown in the microscopic analyses here tabulated, especially in the amount and in the size of the graphite flakes. The first two columns give analyses of specimens taken from the ore dump. The fine flake rock probably came from the top of the bed while the big flake sample represents the central portion.

Quantitative microscopic analyses of the Flake Graphite Company's ores

		No. 798 Ore dump fine flake	No. 799 Ore dump big flake	No. 799a Back stope " best ore "	
APPROXIMATE COMPO- SITION BY WEIGHT	Graphite.....	4.5	7.0	10.0	
	Biotite.....	trace	3.0	7.0	
	Chlorite.....	trace	3.0	trace	
	Andesine.....	31.8	1.0	10.0	
	Quartz.....	47.5	75.0	70.0	
	Augite.....	5.5	.....	.....	
	Pyrite.....	6.0	9.0	7.3	
	Apatite.....	2.2	2.0	.2	
	Titanite.....	2.5	.....	.....	
TOTAL.....		100.0	100.0	100.0	
SIZE OF THE GRAPHITE FLAKE	DIAMETER IN HAND SPECIMEN	Average.....	.50x.68 mm	.76x1.10 mm	.66x.90 mm
		Maximum.....	.92 mm	2.40 mm	1.96 mm
		Minimum.....	.30 mm	.50 mm	.42 mm
	THICKNESS IN THIN SECTION	Average.....	.039 mm	.064 mm	.053 mm
		Maximum.....	.059 mm	.149 mm	.080 mm
		Minimum.....	.027 mm	.031 mm	.039 mm

Concentrates

GRADE		No. 2 Flk	No. 2 Flk	No. 3 Flk	No. 4 Flk	Dust D3X
DIAMETER	Average.....	.42x.58 mm	.43x.66 mm	.27x.48 mm	.14x.23 mm	.09x.15 mm
	Maximum.....	.91 mm	.90 mm	.70 mm	.59 mm	.20 mm
	Minimum.....	.20 mm	.28 mm	.20 mm	.09 mm	.04 mm
		Some quartz very little biotite	Some quartz very little biotite	Some quartz some biotite	Lots of biotite and quartz	Biotite, quartz, feldspar in large amounts
	Chemical analysis ¹	90.80	86.88	87.54	54.40	46.80

¹ Chemical analyses by H. F. Gardner.

It is a quartz-schist having a considerable range in the amount of the micaceous minerals, the small-sized flake sample showing the lowest content. The injection of the pegmatites has mussed up the flakes, twisting and fraying them into fantastic forms. In the proximity of pegmatites the ore is usually more abundant in graphite and in pyrite. The distorted and split character of the flake present special milling problems. It might be well to ignore this form of schist in mining, selecting rock free from pegmatitic material. The ore from the back stope is regarded by Mr R. L. Dowling as the best ore. True, it probably does carry a high percentage of graphite, but the mica is present in detrimental amount.

Mining practice. The ore is hauled up the steep slope in small mine cars by a cable system to the surface, onto a mill car loading platform. From there the ore is transferred by a chute to automatic dumping cars and pulled into the rear of the mill. An air compressor of Ingersoll-Rand manufacture, located in a shed near the portal of the slope, supplies air for the drills. In the same building is located a very neat Delco generator driven by a gasoline-kerosene engine which keeps a storage battery charged. The latter supplies the electricity for lighting the mine and the mill.

It is the opinion of the writer that the original mining layout was unfortunate. The present system necessitates pumping and a double car system. It is suggested that the old opening, which was known as "No. 2," be extended farther down the dip and along the strike to the west and overhand stoping be employed in working up the dip, allowing the loosened ore to gravitate to the mine cars below. This drift might be extended to the bottom of the

present slopes, furnishing two exits. Such a method of procedure is probably necessary to secure an amount of ore commensurate with the mill capacity.

The mill. The mill structure is the best constructed of those visited by the writer. It is built of reinforced concrete and utilizes the natural hill slope in gravity systems. The milling practice is described in detail under the head of "Concentration" to which the reader is referred.

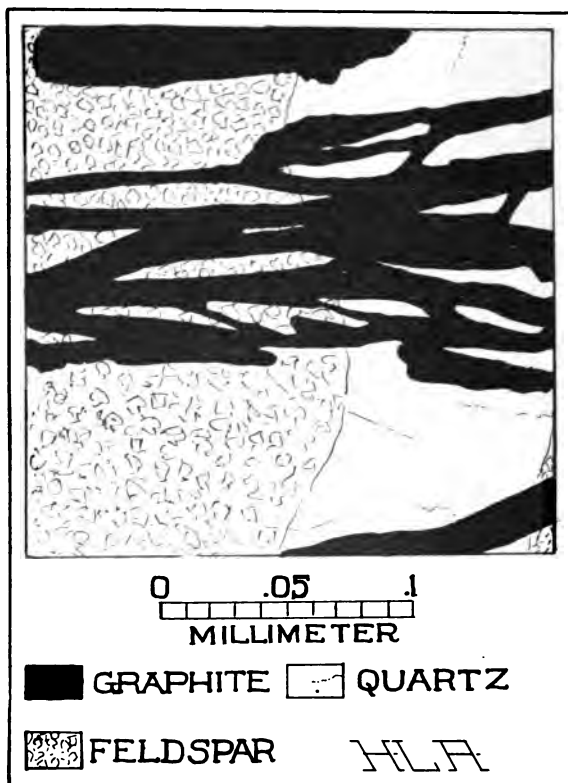


Fig. 23 Camera-lucida drawing of microscopic thin section of ore from the Flake Graphite Company's mine, showing a graphite flake split into thin plates by the injection of pegmatite. Specimen No. 798. Magnification X 430. H. L. Alling, 1918.

Future of the property. At the present time the Flake Graphite Company is taking over the property of the Empire Company and making changes in the mill equipment and organizing for active operations in the near future, probably in the spring of 1918.

In all probability there is a great supply of ore. The graphitic

schist has been followed along the strike for 1500 feet and the incline has followed the 10-foot ore bed down to 200 feet or more. We can assume: $1500 \times 200 \times 10 = 3,000,000$ cubic feet of ore rock. A cubic foot weighs about 168 pounds, hence there is 500,000,000 pounds or 2,500,000 tons of ore. No diamond drilling has been done on the property. There is the possibility of the granite cutting the ore.

The Graphite Products Corporation

Location. This mine, now in active operation, is located 1 mile southwest of King's Station, 4 miles north of Saratoga Springs, in the township of Wilton, Saratoga county, the exact location being indicated by crossed hammers on the geological map of the Saratoga quadrangle.¹ It lies about one-half of a mile west of the Saratoga-Mt McGregor fault in the southeast corner of a block of the Grenville quartzitic area mapped by Cushing.

The property was first opened about 1910 by the Saratoga Graphite Company,² which worked it in a small way for two years. After the lapse of some time the present company assumed control and began the work of enlarging the mine and plant, and is now operating it.

The mine is reached by following the state highway leading to Glen Falls for a distance of 3 miles, keeping north on a good dirt road for $1\frac{1}{4}$ miles. A sharp left-hand turn up the hill leads to the mill.

Workings. There are two distinct outcrops now being worked. The original pit as left by the Saratoga Graphite Company, is 75 by 30 feet and has been abandoned. To the west a new opening has been made that extends 375 feet along the strike; the latter varies from N 50° W to N 75° W. From this pit on the south side a number of inclines have been driven on a slope from 38° to 42° S 15° W, these meeting two parallel horizontal drifts which follow the strike. In them mill car tracks were laid. This working is locally known as the mine.

To the north, across a swamp, at a distance of 400 feet, is the quarry, where open cut methods are employed. At the present time this pit is the main source of graphite. It is 200 by 80 feet, and 30 feet deep, extending east and west. Farther west a number of

¹ N. Y. State Mus. Bul. 169.

² Newland, D. H., N. Y. State Mus. Bul. 161, p. 34 and Bul. 190, p. 30.

prospect holes show that the schist can be traced a long distance along the strike.

Geology and structure. The same stratum of quartz schist, which carries the graphite, occurs in the two outcrops in the mine and in the quarry, repeated by faulting. The stratigraphy prevailing at both localities is in accord with such a suggestion. Starting "in the bottom of the ravine by the old mill . . . a serpentinous limestone forms the bed of the brook for some distance."¹ The next rock to the north is a para-amphibolite (see left end of section, figure 24), dipping 30° south. If this rock is the Beech Mountain amphibolite it would be reasonable to expect that the sillimanite schist (Catamount schist) should succeed it in passing northward, or stratigraphically downward. This proved not to be the case; the amphibolite grading into the quartzite, which is vitreous but as the crest of the knoll, under which the horizontal drifts are located, is reached it was found to be crumbly and injected and saturated by the old Laurentian granite, producing a syntectic rock which in a few cases is an augen-gneiss. This probably is the Swede Pond gneiss. The northern slope of the knoll is composed of siliceous limestone — the Faxon. Between the limestone and the quartzite is a lenticular mass of the metagabbro. Beneath the limestone is the graphitic schist shot through by "pegmatitic material which forms knots ("nuts") and stringers . . . probably due to injection from a granite magma."² Here 10 to 15 feet of the ore bed is exposed. The tunnels which have been driven along the course of the beds at points below the outcrop tap the fresher portions of the bed. The floor of the inclines exhibits slickensided surfaces suggesting that a fault, parallel to the bedding, occurs here.

The writer was unable to observe the footwall rock, which would normally be the Hague gneiss or its equivalent. A swamp beyond compels the writer to put a gap in the cross section. Almost anything may have happened in this interval, in view of the faulting that characterizes this locality. Pegmatite, quartzite and metagabbro are the rocks next encountered. That the last is not a para-amphibolite but an igneous rock has already been suggested by Newland.³ Beyond is another depression, furnishing but a single outcrop in the nature of a reddish garnetiferous quartz-feldspar para-gneiss that is difficult of classification unless it be the Hague gneiss. If this be the case, then between the metagabbro and the

¹ Newland, D. H., N. Y. State Mus. Bul. 190, p. 31.

² Ibid.

³ Ibid., p. 30.

Quantitative microscopic analyses of the Graphite Products Corporation's ores

			No. 783 West end of the mine	No. 787A The quarry ore injected with pegmatite	No. 786 The quarry ore free from pegmatite
APPROXIMATE COMPOSITION BY WEIGHT	Graphite.....		7.7	7.9	.....
	Biotite.....		1.9	.6	.....
	Chlorite.....		trace	2.8	.....
	Feldspar.....		9.2	30.3	.....
	Quartz.....		73.2	55.2	.....
	Serpentine.....		5.8	trace	.....
	Pyrite.....		1.2	3.2	.....
	Apatite.....		1.0	trace	.....
	TOTAL.....		100.0	100.0	.....
	Species of feldspar.....		Andesine	Microcline and andesine	.....
SIZE OF THE GRAPHITE FLAKES	DIAMETER IN HAND SPECIMEN	Average.....	.70x.42 mm	1.43x.70 mm	.68x.41 mm
		Maximum.....	1.30 mm	4.25 mm	.80 mm
		Minimum.....	.20 mm	.45 mm	.30 mm
	LENGTH IN THIN SECTION	Average.....	.75 mm	.77 mm	.....
		Maximum.....	1.30 mm	2.00 mm	.....
		Minimum.....	.30 mm	.30 mm	.....
	THICKNESS IN THIN SECTION	Average.....	.065 mm	.071 mm	.....
		Maximum.....	.120 mm	.150 mm	.....
		Minimum.....	.030 mm	.031 mm	.....

Graphite Products Corporation concentrates

Specimen no.....	789a	789A	789B
Grade.....	Mill concentrate	Finishing mill no. 1	Finishing mill no. 2
Average diameter.....	.205 mm x .437 mm	.372 mm x .677 mm	.268 mm x .451 mm
Maximum diameter.....	.600 mm	.924 mm	.831 mm
Minimum diameter.....	.133 mm	.194 mm	.233 mm

Hague there is the possibility of another bed of the graphitic schist. Climbing out of the depression upon the low ridge a view of the quarry can be had. The rocks here are faulted and penetrated by pegmatite. A better idea of the conditions that prevail here can be

extraordinarily long diabase dikes running from the north-northeast to the south-southwest. Five hundred feet west of the concentration mill is another one that evidently was not observed when the mapping of the quadrangle was in progress. The width of this dike is 36 feet. This has an important bearing upon the mining conditions, both in the mine and in the quarry. At the time of our visit the west end of the drifts was about 90 feet away and headed for it. A test pit on the strike to the west of the dike shows that there is very little or no displacement associated with the dike. Thus it would seem that the drifts will eventually cut through the diabase and the miners will find that the ore continues on the farther side. Likewise the further extension of the quarry will be hampered by the same dike. A much smaller one located just across the road from the finishing mill is parallel to the other but is only 10 inches wide.

The ore. This is the normal schist, similar to the American, Hague, Flake and Hooper ores, but the pegmatite stringers have caused some variation in the composition, including the graphite content. For the exact composition, see the tabulated microscopic analyses. "The outcrop is badly weathered and softened through oxidation of the contained pyrite, which is rather plentiful in the unweathered rock."¹ The material from the bottom of the inclines along the drifts is apparently better, where about 20 feet of rock is shown. The expense of operating the mine by the underground methods has led the company to exploit the quarry much more extensively at the present time than the mine. The schist now being worked "contains less mica than the more easterly ledges and with the coarser size of the flake affords better material for mill treatment."²

Mining practice. The quarry is a recent venture and the methods in use are in an experimental stage. The ore is hauled up an inclined track by a donkey engine and dumped into wagons. The teams follow the road to the east end of the mine and the ore is dumped down a chute into the mine cars on the upper drift level, which carry it directly into the concentration mill. It is the plan, if the quarry holds out, to provide a better and more permanent system.

The mine is being worked only in a small way at the present time.

¹ Newland, D. H., N. Y. State Mus. Bul. 190, p. 31.

² Ibid.

The drifts are being driven westward and some overhead stoping is being done as well as working down the dip.

Milling practice. The Graphite Products Corporation, which took an active interest in the property in 1915, has constructed a new concentration mill, the old one of the Saratoga Company being fitted out as a finishing mill, a little distance away. The usual Adirondack practice is in force: crushing, stamping, buddling, screening and drying. The finishing mill uses Hooper pneumatic jigs which prepare the flake for the market.

The mill water is secured from the small stream that flows past the mill. The brook valley has been dammed and receives the tailings. The water is filtered through sand banks and used over again. In the late fall the floodgates in the dam are opened and the spring freshets carry the accumulated tailings down stream, emptying the reservoir.

Summary. Cushing says that "much the same assemblage of rocks" [is shown on both the Flake and Graphite Products properties] "and the general similarity of the rock association strongly suggests that we are dealing with the same rock horizon."¹ With this opinion the writer is in full accord. Isoclinal folding, accompanied by some overthrust faulting, characterizes the Flake property, while this locality exhibits repeated faulting. This is very fortunate for the Graphite Products Corporation in that it has exposed two beds, and possibly a third.

Amount of ore. It would seem as if there was a large store of graphite rock on this property, but the complicated structure of the quarry, especially, demands careful work as the operations are continued.

The "Hulett's Landing" Prospect

"A very low-grade deposit of graphitic quartzite was discovered by Prof. J. F. Kemp on the east shore of Lake George about 3 miles back of Hulett's Landing. A peculiar feature of this deposit is the fact that the hanging wall is a very large eruptive dike. As in the Hague mine the 'vein' seems to have been a line of weakness. The flake of this deposit is very small and of too low grade to be of any value."²

Dr W. McKim Marriott reports³ that in 1916 he collected specimens from an outcrop that occurs near Long pond, which he states

¹ Cushing, H. P., N. Y. State Mus. Bul. 169, p. 148-49.

² The Mineral Industry for 1902, p. 347.

³ Letters of September 9 and 12, 1917.

is apparently of considerable extent. He was kind enough to send the writer several samples that bear out Professor Kemp's opinion that they are of too low a grade to demand any attention.

It would appear that the deposit is of the usual graphitic schist, outcropping along the ridge between Lake George and Lake Champlain. The eruptive dike may well be the metagabbro. The reader is cautioned to interpret the word "vein" as it is used above to mean a bedded deposit.

The Macomb Graphite Company — Popes Mills Graphite Company

The mine is in the township of Macomb, St Lawrence county, south of Black lake, $1\frac{1}{2}$ miles southeast of Popes Mills, within the Hammond quadrangle.

Workings. "The cut shows a finely laminated graphite quartz-schist complexly foliated and corrugated. It may represent the highly metamorphosed deposits of organic material near the shores of the [pre-] Cambrian sea. The contact line of the indurated Cambrian sandstone is irregularly disposed as the northern boundary of this locality. The laminated deposit is crumpled, friable, quartzose and contains a small proportion of iron [pyrite]. The property has been worked to a limited extent by a small company under the name of the Macomb Graphite Company. A section about 75 feet long and nearly 15 feet deep into the face of one of the folds has been made. The structure is uniform and rich in graphite. The company mined about 100 tons of rock for experimental purposes. The deposit seems to grow richer and the percentage of the iron [pyrite] to decrease with depth. Although the milling was done with rather crude equipment the yield was from 15 to 20 per cent of graphite.

"Several tons of excellent concentrates were produced, averaging more than 90 per cent of carbon. The product was distributed to various manufacturers to determine its practical value for lubrication, foundry work, metallic paint and other uses.

"The reports were highly satisfactory. For lack of capital the company has temporarily ceased operations after having worked out the major problem of extraction."¹

Cirkel² says: "Some development work was done last year (1906) on a prospect near Popes Mills, town of Macomb. The graphite occurs as fine scales in schist and the deposit is said to be extensive.

¹ Mills, Frank S., Eng. & Min. Jour., Feb. 22, 1908, 85:397.

² Cirkel, Fritz, "Graphite," Can. Dep't. of Mines, Mines Br. 1907, p. 57.

About 500 tones of rock have been taken out and a mill has recently been completed." The property has laid idle for several years.

It would appear that this deposit is of the very fine crystalline form that usually is referred to as amorphous. Apparently the metamorphism of the Grenville rocks has been less severe in the northwestern Adirondacks than in the southeastern areas. Thus the carbon has not been so completely recrystallized to graphite. The material from the Macomb locality is well suited for certain forms of lubrication, foundry work, etc., but is not crystalline enough to be used in the manufacture of crucibles. It is understood that the Macomb Graphite Company has, within recent years, relinquished its holdings on the mine to the Popes Mills Graphite Company, although it still operates the mill.

Size of concentrate

Average diameter.....	.145 mm x .202 mm
Maximum diameter.....	.42 mm
Minimum diameter.....	.09 mm

The Rossie Prospect

Beck¹ says that graphite "is thought to exist in workable quantities in the town of Rossie and elsewhere in St Lawrence county."

"In St Lawrence county some attention has been given to a deposit occurring on the Indian river about 3 miles [probably south] from Rossie village. The graphite forms the principal constituent of a schist, through the body of which it is distributed richly in very small scaly particles. It is a crystalline graphite, but too fine in size to be easily separated. Trial shipments of the crude material were reported to have given satisfactory results when used for foundry purposes."²

The Smith Graphite Property

This property was visited and mapped in detail during the summer of 1918 after completing the report on the Adirondack graphite deposits. This deposit is situated in the township of Chesterfield about 4 miles directly south of Clintonville and one-half of a mile south-southeast of the southern end of Trout pound within the limits of the Ausable sheet.

Topography and physiography. The graphite schist occurs in a narrow valley extending northwest and southeast as a side valley

¹ Beck, Nat. Hist. N. Y. State, pt 3, Mineralogy, 1842, p. 421.

² Newland, D. H., N. Y. State Mus. Bul. 120, p. 30.

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TOP SECRET MAP OF THE GEO W SWITH 1950

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to the long north and south depression that is traceable from Trout pond to Elizabethtown. The origin of this side valley is directly due to the easily eroded Grenville strata which here are composed in large measure of limestone. The valley walls and inclosing hills are of igneous rocks that are much more resistant to destructive forces.

The continental ice sheet widened the north and south valley as well as scraped off the decomposed rock decay which had formed during the interglacial periods. During the retreat of the glacier, heavy glacial streams flowed through the main valley alongside of the ice tongue which occupied the valley bottom. Extensive boulder trains and deltas were deposited, which can be traced for a long distance southward. The ice tongue deposited crescent-shaped moraines north of Lewis and one in the side valley in which the graphite schist is exposed. This moraine is convex up stream showing that it is the work of the continental ice rather than that of a local glacier. Although it is somewhat dissected yet it has forced the present brook to seek a course to one side of the valley forcing it out of its normal course. Morainal ridges and glacial silts obscure much in this side valley and greatly interfere with detail mapping.

The pits. Graphite was discovered years ago by marble men seeking a supply of serpentinized limestone (verd antique). In their original search they were disappointed. The property is now owned by George W. Smith of Keeseville, N. Y. A large number of pits and small diggings have been made to determine the extent and quality of the graphite rock. Two of them are situated on the east side of the valley where the schist is exposed, dipping from 55 to 40° to the east. From north to south these pits will be called No. 1 and No. 2 respectively. Seven hundred feet to the southwest of these pits are a number of diggings and pits situated near a wood road. The rocks exposed here are nearly horizontal. To the east of the road they dip to the northeast at a low angle, while to the west of the road the strata dip in the opposite direction.

Geology and structure. It is evident from the behavior of the graphite schist and associated Grenville rocks that they have been folded into a anticline, which is slightly tilted to the west and pitches to the north (see figure 25). The present surface of the region has so truncated the graphite schist that the line of outcrop forms a U-shaped pattern on the map. While the stratigraphy of the Grenville series in this locality is in many respects similar to

that exposed on the active graphite properties in the southern region, there are some interesting variations.

Above the ore is a bed of quartzite about 50 feet thick that is evidently equivalent to the horizon called the Swede Pond quartzite. On top of this quartzite is a bed of crystalline limestone which is commonly siliceous and contains various green silicates that have been changed to serpentine. It is about 50 feet thick and is surmounted by another layer of quartzite. The question arises whether this lime formation is equivalent to the so-called "sandy" limestone which is shown on the southern edge of the Dixon-Faxon properties. If this is the case then it is a little difficult to explain the second stratum of quartzite. Thus it is proposed that this limestone be called the Trout Pond limestone and the two quartzite formations be called the lower and upper Swede Pond. It is of course possible that the Trout Pond limestone is replacing the Swede Pond quartzite in somewhat the same way that the Faxon limestone was found to do on the International Graphite Company's property. On the southern slope of the prominent ridge that limits the valley on the west a quartzite-carrying graphite was encountered. It is possible that this is the Bear Pond schist which constitutes the ore on the Bly property, or this graphite may have been introduced into the Swede Pond by the action of adjacent igneous rocks. From a study of a thin section cut from this material, the writer concludes that the former interpretation is probably the correct one. The so-called sandy limestone is either absent or so highly silicified that it could not be recognized as such. At the Flake Graphite Company's mine (Greenfield, Saratoga county) a parting composed of limestone and green quartzite separated the ore into two distinct layers. On the Smith property a thin stratum of limestone occurs near or on top of the graphitic member.

Beneath the ore is another limestone that seems to be a new one in Grenville stratigraphy. While it is conceivable that this may be a phase of the Faxon it is deemed best to introduce a new term, the Chesterfield limestone. This is some 50 feet thick. There is some uncertainty in regard to the rock that lies beneath the Chesterfield, as exposures are very rare. In the core of the anticline loose boulders of a para-amphibolite were encountered in sufficient numbers to justify the conclusion that they came from a bed situated beneath the limestone. No evidence could be secured that the garnet-sillimanite gneiss of the southern area, named the Hague gneiss, was present.

The ore. The graphite rock appears to be the Dixon schist. In general it is a quartz schist with feldspar, graphite, pyrite, apatite, zircon and biotite. The ore from pits no. 1 and no. 2 is greatly superior to any found elsewhere on the property. Here it is essentially a quartz schist with 14 to 18 per cent graphite and a surprisingly small mica content. On the west side of the valley the ore that is exposed near the wood road is of poor quality with a low graphite and a high mica content. There is considerable improvement, however, in depth, but no ore has as yet been encountered

Quantitative microscopic analyses of the Smith ores

		SECOND PIT	PATH SUMMIT OF ANTICLINE	PATH 5 FEET BELOW SURFACE	PATH 3 FEET 8 INCHES BELOW SURFACE	HILL 12 FEET BELOW SURFACE	HILL 3 FEET BELOW SURFACE	
		900	902	902a	919	920	921	
Approximate composition by weight	Graphite.....	14.6	3.0	6.9	7.8	14.0	6.1	
	Biotite.....		14.0	8.5	13.0		4.5	
	Chlorite.....	.3						
	Feldspar.....	1.2	40.0	40.0	31.3		21.5	
	Quartz.....	82.3	14.6	26.0	26.9		37.6	
	Pyrite.....	.2	6.0	15.3	20.0	11.5	29.5	
	Apatite.....	.1	.4	.4	.3		.7	
	Garnet.....		12.0					
	Diopside.....			.3		23.0		
	Serpentine.....					50.2		
	Kaolin.....	.8						
	Sillimanite.....		10.0		.3			
	Zircon.....	.5						
	Hematite.....					1.3		
	Zincblende.....						.2	
Total.....		100.0	100.0	100.0	100.0	100.0	100.0	
Graphite.....		18.92	2.94		7.34	12.6	8.5	
Chemical analysis.....								
Size of the graphite flakes	Length in thin section	Average.....	1.31 mm	.52 mm	.45 mm	.59 mm	.77 mm	.54 mm
		Maximum.....	2.20	.90	.70	1.00	1.25	.80
		Minimum.....	.44	.26	.30	.33	.32	.31
	Thickness in thin section	Average.....	.038 mm	.048 mm	.050 mm	.034 mm	.075 mm	.039 mm
		Maximum.....	.060	.065	.100	.068	.200	.071
		Minimum.....	.010	.017	.012	.010	.040	.015

on the west limb of the anticline that equals the ore from the first two pits. Furthermore, the ore on this side of the valley has been affected by the action of the igneous rocks which have penetrated the ore in some places as pegmatite dikes which have developed, in some local cases, traces of graphite by contact action. Specimens from the bottom of a pit dug at the side of the wood road revealed the presence of pyroxene (diopside) which has been developed by contact metamorphic action, reminding us of the Rowland-Interna-

tional ores. In all the surface exposures the quality is low, but improvement may in general be looked for in depth. It is possible that the surface layers exposed on the west limb of the anticline are the lower beds of the Swede Pond quartzite into which the graphite has been carried by igneous activity. The ore on the west limb is much more available than the material on the east limb, in that quarry methods could be employed, because the graphite schist lies in a horizontal position, but the inferior character forces us to place our emphasis upon the east limb in spite of its greater dip.

The graphite schist in pits nos. 1 and 2 is separated into several seams by layers of yellow quartzite. In no. 1 pit the following order was found in descending order: 2 feet of graphite schist, 9 inches of quartzite, 1 foot 6 inches of graphite, 1 foot 6 inches of quartzite, 4 feet 10 inches of graphite schist, making a total of 8 feet 4 inches of graphite schist. In no. 2 pit the beds occur as follows: 4 feet 6 inches of graphite schist, 2 feet of quartzite, 9 inches of graphite, 2 feet of quartzite, 9 inches of graphite, making a total of 6 feet of graphite ore. This alternation of graphite and quartzite is unfortunate in that it will complicate the mining practice, involving as it will the rejection of some of the blasted rock.

Microscopic examination of the yellow quartzite, that separates the graphite seam into several layers, seems to indicate that this is in part igneous material. It is quite possible that the igneous activity has removed the graphite from the barren zones and concentrated it in the other portions of the bed. If this should be true it might interfere with the uniformity and character of the rock in depth. This suggestion is furthermore strengthened by the finding of large flake graphite which has the appearance of being of the contact type. This occurs near the bottom of the Dixon schist in contact with the Chesterfield limestone.

About 1000 feet north of no. 1 pit a ridge of the lower Swede Pond quartzite dips at an angle approaching 90° . It is inferred from this outcrop that the graphite rock is situated thus to the west of this exposure, but as this account is being written the presence of the ore at this spot has not been proved. If, however, this should be established it would be safe to assume that the ore can be traced for about 2000 feet along the eastern limb of the anticline. Assuming 6 feet for the thickness of the graphite ore and that the bed should be followed for 300 feet down the dip, the available tonnage of the schist is calculated to be 300,000 tons.

There are no indications that the total depth to which the work can extend is limited to 300 feet, but as the dip undoubtedly will increase in depth, which is especially true of the ore farther north along the strike, the mining difficulties will increase. It is quite possible that preliminary work could be conducted by quarrying the ore along the strike from a point near no. 1 pit southward.

The number of igneous rocks present on this property is not absolutely known, but according to the present knowledge the Algonman granite and the anorthosite are present. The latter rock occurs as small bosses which have been severely squeezed so that the rock resembles the crushed or "pulpy" phases of the rock as shown throughout the Adirondacks.

Farther away from the sedimentary rocks the amount of Grenville admixture becomes less until a fine-grained granite makes up the bulk of the rock exposed. This is in all probability the Algonman granite. In this granite a large number of inclusions of amphibolite occur in a manner quite similar to the inclusions found in the so-called Laurentian granite of St Lawrence county. The microscope points very clearly to the fact that these inclusions are igneous and it is quite possible that they represent the ancient metagabbro which Cushing believes to be the oldest eruptive in the Adirondacks. If this is so, then they must be older than the Laurentian granite; and in view of the fact that the term Laurentian is primarily applied to the older granite, the term pre-Laurentian is used in the legend on the map of this property.

Syntectic rocks. The valley is delimited on both east and west by ridges composed of igneous rocks which present a number of perplexing problems that up to the present time have been only partially solved. The relation between the Grenville rocks which occupy the valley and the igneous rocks is apparently an eruptive one rather than that they exist together by virtue of a fault. The east valley wall is composed of a syntectic rock resulting from the assimilation of Grenville rocks by an igneous magma.

On the west, the transition from the sediments to the granite can be traced much more satisfactorily. It is possible to recognize the different forms for several hundred feet even though they have been saturated by the solutions of the igneous rock. These blend gradually into rusty assimilation products which give away in time to the normal granite.

The last igneous rock that is recorded in the region is the diabase (olivine-augite-camptonite), two dikes of which were found. One

is near the pit on the west limb of the anticline cutting the Chesterfield limestone. It is 4 feet 10 inches wide and runs from north 65° to north 80° west. The other dike is situated on the west hill slope and is 1 foot 9 inches in thickness and extends across the foliation of the granite north 76° east.

Water supply. It is quite possible that there is a sufficient amount of water available on the property. The outlet of Trout pond alone may be sufficient although more water could be secured from this brook after it had been enforced by the stream that crosses the anticline, as shown on the map. If, however, this supply proved to be too scanty it is quite possible that water could be secured for boiler and mill use from Trout pond.

Transportation. The secondary roads from the pits to the main highway are in fair condition. The renewing of the culverts and bridges and a little grading would make the property very accessible. It is 4 miles by highway to Clintonville through which the Ausable Forks branch of the D. & H. railroad runs. This road although quite passable for a motor car is rather hilly and it might be that some improvement would be necessary in order that heavy laden trucks could use it.

Summary. This property exhibits in some places ore that is of unusually high quality. Some care must be taken to establish the exact limits of the ore on the west and on the east sides of the valley. At the present time the position of the contact between the ore and the igneous rocks is only approximately known. However, it is certainly worth while to conduct exploratory work on this deposit.

SUMMARY OF THE SOUTHERN AREA

It is the bedded deposits of the graphitic schists of the southern area that are the commercial deposits of the Adirondacks. We have seen that there are four distinct types of ores.

1 The normal quartz-schist with 5 to 7 per cent of graphite which is the valuable rock at the American Graphite Company, the Faxon property, the Lakeside mine, Hooper Brothers' mine, the Champlain Graphite Company, the Adirondack Mining and Milling Company, the Silver Leaf Graphite Company, the Flake Graphite Company, and the Graphite Products Corporation. The rock worked at all these localities is very probably the same stratigraphic unit, referred to as the Dixon schist. It exists as two beds or lenses at the Dixon, Faxon and probably at the Flake mines, but in the other properties it is represented by a single bed. In general, the formation varies in thickness from a maximum of 30 feet to a minimum of 3 feet. The upper portions of the Dixon schist are usually micaceous, which seems to be true of the bottom layers as well. As a general habit an increase in the feldspar percentage is accompanied by a rise in the biotite-chlorite content, although there are a few exceptions to this rule.

2 The second type is the feldspar-quartz schist with 6 per cent of graphite and 10 per cent of micaceous minerals. This is exemplified by the Bly ore. It is the writer's opinion that this schist represents a distinct and different horizon from the Dixon schist. It would seem as if it did not have such a great areal extent. This is the Bear Pond schist.

3 The third type is a phase of the Dixon schist affected by a mild form of contact metamorphism, which has developed pyroxenes and tourmaline and redistributed the graphite resulting in an abnormally high graphite content in certain layers. This is the International-Rowland-Sacandaga type.

4 The last group has only one known representative; the Rock Pond ore, which is a meta-arkose ("arkosite"), being composed almost entirely of potash feldspar. Its stratigraphic position is unknown.

There is a practical basis for such a classification. Milling practice rules out, for the present, the last three classes. It may be that with the development of milling processes, already suggested, some of these can be successfully worked in the future. The slightly contact metamorphosed beds present a very variable rock

that is difficult to crush without undue attrition of the valuable mineral. The chief objection to the Bly ores is the high mica content. The commercial possibilities were touched upon while discussing the Bear Pond Mountain region.

Average of the quantitative microscopic analyses of graphitic schists of the southern area

The properties from which specimens have been micro-analysed are capitalized.

	Normal Dixon schist	Slightly contact metamorphosed Dixon schist	Bear Pond schist	Rock Pond "arkosite"
Graphite.....	6.9	7.6	6.2	1.6
Biotite.....	3.3	3.4	9.4	.3
Muscovite.....				.1
Chlorite.....	6.1	1.4	1.4	6.7
Sericite.....	little	little	little	little
Andesine.....	15.7	16.9	39.5	.7
Orthoclase.....	.7		9.5	10.3
Microcline.....	.4	13.5	.6	52.3
Quartz.....	61.6	24.6	26.1	9.6
Pyrite.....	3.5	7.9	7.3	17.1
Apatite.....	1.0	1.0	1.0	.1
Garnet.....	.1			
Diopside.....	.2	22.8		.5
Titanite.....	.3	.4		.05
Serpentine.....	.2		trace	
Tourmaline.....	none	.5%		
Carbonates.....	trace	trace	trace	.4
Sillimanite.....	none	none		.05
Galena.....	none	none		.2
TOTAL.....	100.0	100.0	100.0	100.0
Represented by.....	DIXON FAXON HAGUE HOOPER CHAMPLAIN Adirondack Silver Leaf FLAKE GRAPHITE PRODUCTS	INTERNATIONAL ROWLAND SACANDAGA	BLY	ROCK POND

Classification of the graphite ores

Dixon schist	Bear Pond schist	Rock Pond arkosite	Slight contact metamorphosed	Contact	Veins
Dixon Faxon Hague Hooper Champlain Adirondack Silver Leaf Flake Graphite Products	Bly	Rock Pond			
International			International	International	
Sacandaga			Rowland Sacandaga	Sacandaga	Rowland

GRENVILLE STRATIGRAPHY

It is the hope of Adirondack geologists that the Grenville series can be "put in order." Up to the present time the succession and the thickness of the beds are unknown, and likewise we are unacquainted with the base and the top of the series. W. J. Miller¹ has made a beginning following I. H. Ogilvie,² but their units are far too large for our use. Most of the geologists are interested in the purely scientific side of the problem, but the writer's task demands that he take a practical as well as a scientific view. Hence he started the field work with the hope that something could be done with the stratigraphy as an aid to the problems of the graphite deposits of the Adirondacks. He feels that he has, in part at least, arrived at something definite.

Composite geological column showing the Grenville stratigraphy of the southern graphite area

Rock	Name	Estimated thickness in feet	Type locality
Top unknown			
Para-amphibolite.....	Beech Mountain....	150	Beech mountain southeast of Graphite
Feldspar-quartz graphite schist....	Bear Pond schist....	30	Bear pond, Ticonderoga
Sillimanite schist.....	Catamont.....	70	Catamont mountain, International property
Limestone.....	.....	20	Faxon property
Quartzite.....	Swede Pond.....	400	Swede pond, Faxon property
Limestone.....	Faxon.....	20	Faxon pond, Faxon property
Quartz-graphitic schist.....	Dixon schist.....	30	Dixon mine
Garnet-sillimanite gneiss.....	Hague gneiss.....	60	Lakeside mine at Hague
Para-amphibolite.....	Dresden.....	120	Township of Dresden, Hooper property
Limestone.....	Johnsburg.....	30	Johnsburg Rowland property
Quartzite.....	Sacandaga.....	70	Sacandaga river, Sacandaga mine
Bottom unknown			
	Total.....	1000	

As the number of beds recognized increased, it became necessary that some name be attached to each one. The names here proposed have already caused some criticism, and rightly so. Geological usage demands that a name should indicate the geographical locality where the formation is typically shown, and furthermore the name should not be preoccupied. Such an ideal has not been realized. This is

¹ N. Y. State Mus. Bul. 170, p. 10.

² N. Y. State Mus. Bul. 96, p. 479.

accounted for by the scarcity of geographical names in the sparsely settled Adirondacks and that the writer was forced to devote his energies to the graphite properties and did not have the time to go exploring over the country in search of typical outcrops. The names are purely tentative, and nothing more. It is the writer's hope, however, that as continued progress is made in untangling the Grenville series more suitable names and better correlations can be proposed.

The practical application of the stratigraphy has already been pointed out. There was hardly a mine that did not have problems that, in a manner at least, were solved by using the knowledge of the succession of the beds. A striking example is the conclusion reached in regard to the amount of ore on the Rowland property. The value is not limited to the question of the amount of ore, but can be used in locating and determining the amount of displacement of faults. In this connection see the Dixon and Faxon properties.

THE IGNEOUS ROCKS

The Algomán. The anorthosite, syenite, granite and gabbro (arranged in order of their age), which compose the younger group of igneous rocks, the writer regards as Algomán in age. They have been so thoroughly discussed in the various bulletins of the New York State Museum as to call for no further discussion. The writer would take more kindly toward the view that the syenite-granite masses represent several different centers of intrusion contemporaneous in age rather than that they represent differentiated portions of a single body.

The name Algomán, perhaps, needs a word in the way of explanation. Correlation of igneous rocks is, at the best, difficult, but the Precambrian rocks of Canada have been studied in sufficient detail to furnish data for numerous correlation tables, twenty of which have been examined. There is a striking similarity in nearly all; there are only two periods of igneous activity prior to the Keweenawan. The other granite of the Adirondacks, Cushing regards as Laurentian. Hence, if we follow Miller and Knight,¹ we are compelled to employ the term Algomán. It furnishes a much desired "handle."

The metagabbro. This igneous rock found on a number of the graphite properties has not received the attention in Adirondack geology it deserves. The cause of this is not difficult to find. It has been pointed out that the amphibolites are often difficult to interpret as they have been derived in a number of ways: (1) Grenville para-amphibolites, (2) metamorphosed basic (femic) igneous rocks such as gabbros, diorites, and diabases, (3) contact metamorphosed impure limestones.² Excluding the last as unimportant in the present discussion, the choice rests between para-amphibolites and ortho-amphibolites. Cushing, and especially Martin,³ lean strongly toward the igneous interpretation. While it is true that some of the amphibolites are igneous, it is not necessarily the case in all.⁴ Granting that some are sedimentary and some are igneous, a distinction between the two is difficult and frequently impossible, for they are often confoundingly alike:

Specimens were collected from rock masses where field relations pointed to a definite origin. Microscopic examination revealed

¹ Miller, W. G., & Knight, C. W., Jour. Geol., 23:588.

² Cushing, H. P., N. Y. State Mus. Bul. 191, p. 15.

³ Martin, J. C., N. Y. State Mus. Bul. 185, p. 57.

⁴ Löwinson-Lessing, F., "Über die chemische Natur der feldspath Amphibole." Ann. de l'Inst. Polytech. Pierre le Grand. St Petersburg, 15:559-76, 1911.

striking similarities and a few differences. The similarities need not be touched upon. It is the latter that are important.

The interpretation of para-schists and para-gneisses should be guided by mental reference to the original unmetamorphosed rock. What kind of a sediment did we have in the beginning? Cushing suggests a calcareous shale.¹ Now as the first point in our examination it is difficult to conceive of a shale without any free quartz. If any original quartz is present in an amphibolite, it gives it a sedimentary look, for basic (femic) rocks are usually lacking in this mineral. But, on the other hand, the absence of quartz does not furnish a reliable criterion for igneous origin, for recrystallization may have brought about the formation of various silicates, using up the quartz present.

The pyroxene-amphibole (the "pyribole" of Johannsen²) content was next examined. It is held by many geochemists that pyroxene is a high temperature mineral, while amphibole is a lower temperature form,³ the change from pyroxene to amphibole being a paramorphic (or "autometamorphic") one. Whatever the nature

**Chemical analysis of para-amphibolite (hornblende schist) from Lead hill,
Ticonderoga**

SiO ₂	48.26
Al ₂ O ₃	13.32
Fe ₂ O ₃	1.41
FeO.....	11.55
MgO.....	6.66
CaO.....	10.55
Na ₂ O.....	3.36
K ₂ O.....	0.80
H ₂ O —.....	.06
H ₂ O +.....	.96
TiO ₂	1.99
CO ₂	.38
P ₂ O ₅	.20
S.....	.20
MnO.....	.14
FeS.....	.....
C.....	None
Less O.....	99.84
	.10

99.74

Collected by E. S. Bastin, analyzed by George Steiger in the laboratories of the United States Geological Survey, U. S. G. S. Bul. 591, p. 40.

¹ N. Y. State Mus. Bul. 169, p. 19, and Bul. 191, p. 15.

² Johannsen, Albert, Jour. Geol. 1911, 19:319.

³ Elsdon, J. V., "Principles of Chemical Geology," 1910, p. 114.

Becke, F., Tschermak, Min. u. Petro. Mitth. 16:327-36.

Clarke, F. W., U. S. G. S. Bul. 616, p. 386.

Lacroix, Mineralogie de la France, 1893-95, 1:668-69.

of the change may be, the process furnishes some aid in the problem. If a large amount of pyroxene (say augite) is found in an amphibolite, it suggests an igneous origin. Martin,¹ for example, points out that the dynamic disturbances of the northwestern Adirondacks (Canton sheet) were sufficient to all but completely transform the pyroxene to amphibole. Thus the absence of augite does not prove a sedimentary origin but may suggest it. On the other hand, the presence of pyroxene points toward igneous origin. In neither case is this criterion conclusive.

Hunting for additional criteria, the writer investigated the feldspars in turn. Now Vogt,² Becke,³ Marc,⁴ and Harker⁵ attempt to present the physical chemistry of the system; albite-orthoclase-anorthite by a thermo-equilibrium diagram. The plagioclase series is an isomorphous one⁶ (solid solutions), while the orthoclase-albite pair is an eutectiferous one.⁷ The third pair, orthoclase-anorthite is very likely similar to the latter. Thus plotting the three component system upon a triangular base, an eutectic line is to be drawn, connecting the two eutectic points. If the feldspar composition in the magma was on the potash side of this eutectic line, the resulting crystals would approach the orthoclase type of feldspar, while if it were on the other side plagioclase would result. But if the position of the molten feldspar was on or near the eutectic line, the solid minerals would be divided, on freezing, into orthoclase and plagioclase, usually in about equal amounts. In examining the slides of the amphibolites, it was found that the undoubted sedimentary types carried a motley collection of all sorts of feldspars with no definite proportion among them, while the igneous varieties carried an evenly split orthoclase-andesine content, for example. A rock with both potash and soda-lime feldspars is termed a monzonite. While it is not certain that the ferromagnesian minerals were original pyroxenes, it seems likely, and hence the writer suggests that the ortho-amphibolites he has encountered are in large measure meta-augite-monzonites, although the name metagabbro is employed as a more general term.

¹ Martin, J. C., N. Y. State Mus. Bul. 185, p. 57.

² Vogt, J. H. L., *Silikatschemelzungen*, 1914, 2:120-21.

³ Becke, F., *Tschermak, Min. u. Petro. Mitth.* (2), 1906, 25:361, 383-85.

⁴ Marc, Robert, *Vorlesungen über die Chemische Gleichgewichtslehre, und ihre Anwendung auf die Probleme der Mineralogie, Petrographie und Geologie*, fig. 68 and pages 69, 111-12.

⁵ Harker, Alfred, "The Natural History of Igneous Rocks," 1909, p. 250.

⁶ Day, Arthur L., & Allen, E. T., *Carnegie Inst. Pub.* 31.

⁷ Warren, C. H., *Proc. Am. Acad. Art and Sci.*, v. 51, no. 3, p. 127-54.

The critical points in the above discussion can be summed up as follows: the criteria for the sedimentary origin of the amphibolites, the presence of original quartz and motley collection of feldspars; for igneous origin, high pyroxene content and evenly "split" feldspars.

These criteria have been used in classifying the amphibolites whose origin was not forthcoming from the field relations. How successfully it has been done can not be tested at the present time, but the hope is entertained that some progress has been made in this difficult problem. The probable age relations of this rock have already been touched upon.

The Laurentian granite. The existence of a granite much older than the Algonian series of eruptives in the Adirondack region seems to the writer to have been sufficiently proved to need but little comment. Its universal habit is to be intricately involved with the Grenville series. This led the early geologists to regard it as a Grenville sediment.¹ Even today this view is entertained by a few.² "The recognition of pegmatitic phases of the rock threw the first doubt upon its sedimentary character," while "the chemical analysis finally settled the question."³ The writer wishes to add this additional bit of evidence which supports the contention that the rock is of igneous origin. At the Dixon-Faxon and Hague localities it was found that the lower beds of the Hague gneiss were soaked and "smothered" by this rock, while the Hooper and Rowland districts show that the Hague gneiss rests directly upon the Dresden amphibolite, the granite being wanting. Its behavior in affecting one stratigraphic unit here, and a different one there and its entire absence in a third locality, is very suggestive of the igneous nature of the rock. As to its age, the reader is referred to the Hooper and Flake occurrences and to Cushing's reasons for regarding it as Laurentian.⁴

SYNTECTIC ROCKS

The lack of uniformity of the rocks, even those usually regarded as wholly igneous, has led the writer to believe that many of the rocks are of "composite character as a result of injection or assimilation, giving on one hand a sediment more or less 'soaked'

¹ Cushing, H. P., N. Y. State Mus. Bul. 77, p. 17-19; Kemp & Hill, N. Y. State Geol. 19th Ann. Rep't, p. r 32-r 35.

² Miller, W. J., N. Y. State Mus. Bul. 182, p. 11.

³ Cushing, H. P., N. Y. State Mus. Bul. 169, p. 21.

⁴ Cushing, H. P., "Age of the Igneous Rocks of the Adirondack Region," Am. Jour. Sci., 1915, 39:288-94, especially p. 292-93.

with igneous material, and on the other hand an igneous rock which has melted into itself or assimilated sedimentary material. Between these two types every gradation exists, thus introducing additional complication and uncertainty."¹ This condition is strikingly the case north of the Bear Pond Mountain region (see northeast corner of the map of that region) in the area between Eagle lake (Chilson lake on the map) and Bear pond. It seems a mistake to map such an area as though of simple composition and origin.

The soaking effects of the Laurentian granite have been pointed out before. Two syntectic rocks have been recognized: the smothered Hague gneiss termed the Trumbull gneiss, and the Swede Pond quartzite when similarly affected. The peculiar habit of the granite in soaking the salic rocks in preference to the subsalic beds has repeatedly been observed.

GRENVILLE STRUCTURE

From the first reconnaissance of the Adirondacks the Grenville strata have been regarded as intensely folded, metamorphosed and foliated. Recently W. J. Miller has raised some doubt as to the validity of such a conclusion.² As the blanket types of ore are members of the Grenville series, it is of great practical importance to know the actual conditions. Overwhelming evidence of strata repeated in reversed order, of synclines and anticlines tightly squeezed, supports the contention that the Grenville has been complexly isoclinally folded, Bear Pond Mountain, the Hooper, Sacandaga, and the Flake properties being specific cases.

Faults come in and play a major rôle, as in the Dixon-Faxon and Graphite Products Corporation districts. The faults are not all of the same age but apparently range from the middle Precambrian to Postordovician in age. Reasons for this conclusion can not be given here.

THE CONCENTRATION OF FLAKE GRAPHITE

Probably the greatest problem confronting the graphite operators of the Adirondacks is the separation of the flake graphite from its associated gangue minerals. The process of separation is usually subdivided into (1) the "concentration," and (2) the "refining" operations. The former is performed in the mills most commonly

¹ Smyth, C. H., Jr., N. Y. State Mus. Bul. 158, p. 143.

² Miller, W. J., "Origin of Foliation in the Pre-Cambrian Rocks of Northern New York," Jour. Geol. XXIV, no. 6, p. 587-619.

situated near the mines, while the refining is rarely practised by the mine operators, the majority of them sending their concentrates to other concerns for treatment.

Ore separation in general is based on marked physical or chemical characteristics of the ore and the gangue: (1) differences in specific gravities, (2) differences in electrical conductivity, (3) selective behavior of a mixture of water and oil upon the surface tension, or (4) upon the magnetic properties of the ore and the gangue minerals. Up to the present time graphite separation is accomplished by specific gravity methods.

"The whole problem of the concentration of graphite is in great contrast to that of metallic ores, in that in the former case we seek to save the light minerals and reject the heavy, while in the latter case the reverse is true."¹

The specific gravity method of concentrating graphite is subdivided into the wet and dry processes. Both methods require that the ore, as it comes from the mine, first be reduced to a pulverized condition. This is effected by various types of crushers, rolls and stamps. A great variety of rock breakers are in use. There are jaw crushers, which are intermittent in action; and the rotary and gyratory types that are continuous in operation. Further crushing is done by rolls which are constructed of manganese steel. The space between the rolls varies from practically nothing to three-fourths of an inch. They are fed with lumps about $1\frac{1}{4}$ to $1\frac{1}{2}$ inches in size. Frequently, however, California stamps are used instead of, or in combination with, rolls.

From this point on, the wet and dry methods differ. In the wet process, which is the one most commonly employed in the Adirondacks, the crushed rock is mixed with water and fed to a series of buddles. These consist of circular tanks $3\frac{1}{2}$ to 4 feet in depth and 16 to 18 feet in diameter, with a slightly convex bottom, so that the floor of the tanks slopes in all directions from the center to the circumference. A vertical shaft, situated in the center of the buddle, carries a tub, perhaps 3 feet in diameter, with a perforated bottom. The mixture of crushed ore and water is fed into this tub by a stationary sluiceway or launder. Thus the ore is made to enter the buddle at the center and is carried toward the sides by the water which is allowed to escape through specially arranged openings, either controlled by manually operated valves or wooden stoppers fitting round holes. The movement and even distribution

¹ Kemp, J. F., U. S. G. S. Bul. 226, p. 513.

of the layers of slime is further assured by the action of paddles or brushes that are attached to (usually) two horizontal arms secured to the shaft. The revolving brushes lightly rub the surface of the material in the tank and gradually slide up the shaft as the buddle is filled up. The graphite flakes, by virtue of the low specific gravity and flaky, scaly nature, are mainly floated to the sides while the heavier and more massive minerals are dropped near the center of the tank. It usually consumes several hours to fill a single buddle so a series of them are employed; while one is being filled another is being emptied.

After the tank is filled, the material is allowed to dry partially and is then shoveled up. The outer portion nearest the wall of the tank is composed of rather clean concentrates. The inner portion, consisting of sand tailings, is rejected, while the middle portion consisting of both graphite and gangue materials, is passed to another buddle for further concentration. Usually two or three buddles comprise the first set and a like number make up the second. Buddles are the favorite form of concentrators in the Adirondack mills; the amount of labor involved in their use, however, has led a few operators to seek a cheaper method.

The buddle concentrates must be further treated. The more common process is by the use of revolving screen reels. "The reels are hexagonal and are covered with screens of various sized mesh. The reels are slightly inclined; the ore is fed into one end and the concentrates thrown out at the opposite end as the reel rotates. Jets of water directed against the outer part of the reel aid in the separation of the graphite and impurities. The latter because of their small size pass through the screens and are thrown away."¹

The common practice in most mills is to regrind the seconds, to crush the quartz and feldspar grains and send it through the screen again. The graphite is then dried. A number of different types of dryers are in use. Both direct and steam methods are employed.

The most common one is the rotary tube form, although a number of specially designed dryers were seen. Final sizing on screens divides the concentrates usually into four grades. These are then ready for the finishing mill.

In some mills, Wilfley jig tables are used, operating upon the buddle concentrates before the reels performed their function.

¹ Miller, B. L., Topo. and Geol. Sur. of Pa. Rep't 6, p. 87-88.

The mill concentrates average:

First grade.....	70 to 80 per cent carbon
Second grade.....	60 to 70 per cent carbon
Third grade.....	25 to 30 per cent carbon
Fourth grade.....	8 to 12 per cent carbon

They are bagged (a bag weighing about 110 pounds) and shipped to the refining mill.

A concrete example of milling practice. It was not possible for the writer to secure data for a complete account of the milling practice in the Adirondacks. The wet process of the Empire Graphite Company, now the Flake Graphite Company, has, however, been clearly set forth by F. C. Nicholas.¹ The writer can do no better than to abstract the article.

The mill, which is arranged on the gravity principle, has a capacity of 200 tons in 24 hours.

The material from the mine is delivered to a rock breaker and reduced to $1\frac{1}{2}$ to 3 inches in size. The broken rock then drops to the rolls, which are 20 feet long by $2\frac{1}{2}$ feet in diameter, which reduce it to a fine sand. This is fed to a second pair of rolls more closely set. The fine powder is then ready for the buddles. The buddles are constructed of reenforced concrete and lined with matched boards, 18 feet in diameter and 4 feet high. The concentrates from the first operation are sent to a second set of buddles. A set of wet screens is next in order, where the graphite flake is divided into two sizes. A rotary steam dryer then removes the moisture. The final process makes use of silk cloth screens that classify the flakes into four sizes.

Since this was written, two banks of five stamps each, manufactured by the Allis-Chalmers Mfg. Co., and another set of buddles have been installed. It is believed that the stamps have replaced the rolls. Final treatment is accomplished in Hooper air jigs, manufactured by the Ticonderoga Machine Company. A classifier is being constructed and will serve to recover some of the graphite in the buddle tailings. A change in the type of the crusher is also being made.

Such changes in the equipment for the concentration of an ore as are found here are evidence of the experimental state of graphite milling.

¹ Min. World, Jan. 4, 1918, p. 18

The equipment of the Hooper mill at the time of visit is very similar to that of the Flake Graphite Company. Crushing, stamping, buddling, screening and drying are the essential steps in the process. Further improvement is being made, the details of which are not made public.

The dry process. Only three mills, so far as the writer knows, have operated with the dry method: the Lakeside mine at Hague, the Crown Point Graphite Company, and the Rowland plant. These have been abandoned and little direct information is available. In the Rowland mill a Newaygo separator, manufactured by the Newaygo Portland Cement Company, was experimented with, but apparently without success.

The finishing of graphite. In the early days of the industry, the mines in the vicinity of Crown Point sent their concentrates to a finishing mill located at Crown Point Center. Power was secured from Putnam creek. As it has long been closed, details of the processes used there are unavailable.

The American Graphite Company maintains its refining mill at Ticonderoga; the Flake Graphite Company and the Graphite Products Corporation finish their products on their own properties.

The machine that is most generally used in the final treatment of the graphite concentrates is the Hooper pneumatic concentrator, a brief account of which is here given.¹

In essence it consists of an inclined frame over which is stretched a broadcloth screen, up through which a continuous series of air pulsations are delivered by a device located below. Two sets of strips are arranged over the cloth screen, the lower group of which is inclined toward one side, while the upper set is inclined in the opposite direction. ". . . and when (concentrates) composed of particles of different gravities are fed upon the (screen) the pulsations through the broadcloth . . . cause the heavier mineral particles to be thrown (settle) to the bottom . . . and are thus guided . . . toward the tailing side of the (concentrator)," ² while the clean graphite is guided by the upper set of strips to the opposite, or concentrating side, thus bringing about a separation of the gangue and the ore.

¹ For a full description, see Richards, "Ore Dressing," p. 820, and Canadian Min. Jour., 30:271-72, 1909.

² Ibid.

CONCENTRATION PROBLEMS

Mechanical ore separation is an ancient art and a modern science. In the western section of the United States ore dressing is on a far firmer basis than in the case of a comparatively small industry like that of graphite. The separation of graphite from the gangue is exceedingly difficult, calling for long experience and mechanical ingenuity, which is rarely available in the graphite areas of the Adirondacks. Numerous failures can be attributed to this cause. During the past 15 years the technology has experienced some remarkable improvements which have revolutionized the practice of ore dressing in general. Graphite separation has suffered from neglect and lays far behind. Still the old process of buddling continues to be the chief method, while flotation and electrostatic separation have been developed without making any impression in the graphite industry of this region.

Table of specific gravities

MINERAL	SPECIFIC GRAVITY
Apatite.....	3.19 to 3.23
Biotite.....	2.70 to 3.10
Chlorite.....	2.65 to 2.96
Feldspar.....	2.47 to 2.67
Garnet.....	3.15 to 4.30
Graphite.....	2.09 to 2.23
Muscovite.....	2.76 to 3.00
Phlogopite.....	2.78 to 2.85
Pyrite.....	4.95 to 5.10
Pyroxene.....	3.20 to 3.60
Quartz.....	2.65 to 2.66
Serpentine.....	2.50 to 2.65
Titanite.....	3.40 to 3.56

These newer processes render it possible to separate a wide range of minerals of close specific gravity, that can not be separated by jigging or slime washing. Even minerals having the slight difference in specific gravity of 0.35 can be treated. The electrostatic method has many admirers and promises to be used more and more. Several large deposits of graphite seen by the writer were regarded of little commercial value because of the large amounts of micaceous minerals present. The separation of biotite and graphite is exceedingly difficult, if not impossible, by the usual processes. If, however, the electrostatic or flotation processes can be adapted to graphite milling, then there are great sources of graphite still untouched that would become available.

Two ores of even identical composition can not always be treated by the same method. On account of the different physical character

in which graphite occurs, amorphous and flake graphite must be treated differently. Difficulties arise if the character of the ore changes as mining operations proceed, and this is regarded as one of the principal sources of trouble. The selection of a method of milling seems to have been made often without any regard to what the general run of the mine was likely to be. Test holes should be made to determine the character of the ore before mill equipment is bought. In fact, the construction of a mill should proceed only when *all* the conditions of the deposit, the character of the ore as well as the extent of the ore body, are fully known.

"It is quite certain that there is no single process that is a universal panacea for all the difficult problems of ore treatment. For certain ores one process is best adapted; for other ores another process. For still other ores the best results may be achieved by a combination of two or three, or even more of the special processes."¹

The presence of micaceous minerals, biotite, phlogopite, chlorite etc. offers the greatest problem. Although they are higher in specific gravity than graphite, the flaky nature of the former prevents separation by gravity methods as they are floated off in company with the graphite. The particles of mica "are of approximate similar size, and being frequently of the black variety (biotite), they may be readily overlooked in the hand specimen or in the graphite concentrate. The easiest method of detecting the mica and of estimating its relative proportion to the graphite, is to examine the material under the microscope when the former can be readily distinguished by its translucency."²

It is quite possible that a more complete separation of the mica can be effected through the electrostatic method. This can be briefly described as follows: It is based upon the fact that graphite is capable of receiving and retaining an electric charge, while micaceous minerals, as well as most of the other gangue materials, refuse to do so. The machine consists of horizontal parallel rods of brass set one above another like the rungs of a ladder, which are charged with a high potential. Down past these flows the dry, pulverized rock; the gangue materials, not affected, fall vertically and drop into a receiver, while the graphite is repelled laterally away from the bars and drops into troughs arranged in front. The process is repeated until a complete separation is

¹ Ingalls, W. R., Eng. and Min. Jour., 1905, p. 643.

² Newland, D. H., N. Y. State Mus. Bul. 179, p. 34.

made. The middlings are sometimes reground to rub off the quartz and feldspar grains still attached to the flakes, and then passed through the machine again.

Mr Charles T. Rowland, president of the Rowland Graphite Company, had a representative of the Huff Electrostatic Separator Company make a thorough investigation covering the milling of the Rowland ore in 1916. He says: "The sample used in making this test was blasted out of the bed, as it was desired to get . . . an average sample of the output of the mine. This report shows that the ore can be milled economically with a good recovery, and that the flake produced is of very high grade and compares very favorably with the best flake now being produced in this country."¹

Cirkel says that "Experiments have . . . shown that . . . (flake) graphite may possibly be separated from the gangue electrostatically, and it is not unlikely that such a process may be worked before long. The writer [Cirkel] submitted a parcel of 100 pounds for preliminary test to the Huff Electrostatic Separator Company of Boston, Mass., and the tailings from this test were without question quite clean. The middlings consisted of graphite with attached gangue particles, and need regrinding before they can be again submitted to the electrostatic treatment. The concentrates appear to be free from rock, but there was some attached gangue. The writer [Cirkel] believes that if this product was submitted to the polishing treatment it is likely that a clean article may be the result."²

The size of the graphite flake is another factor that must be taken into consideration. A rock carrying a coarse flake is more desirable, other things being equal, since the value of the concentrates and the economy and perfection of the separation is in direct proportion to the size. One of the many factors involved is the easy crushing of the rock. Among other things that affect the ease of crushing is the mineralogical make-up of the ore. The presence of pyroxene (diopside), such as was seen in the Rowland ore, offers serious objections to its utilization. The crushing machines must be designed and adjusted so as to cause the least amount of attrition to the flake. Moreover, there is the actual condition in which the flake is found. It was repeatedly observed that where folding, squeezing and igneous activity have taken place, the flake has been frayed out into fantastic forms, resulting in the splitting of the

¹ Rowland, Charles T., letter of Oct. 16, 1917.

² Cirkel, Fritz, *Trans. Can. Min. Ind.* 1912, 15:267

flake into thin, bent plates which under rolls or burr-stones would be reduced in size. This would lead the writer to suggest that ore near pegmatites be carefully examined before being sent to the mill, as any fraying of graphite should cause its rejection.

It is quite possible that a preliminary roasting of the ore prior to crushing will have a very beneficial effect, both upon the quantitative results of separation and upon the quality of the graphite that is recovered. The object of such a treatment would be the disintegration of the ore by chemical and physical changes in modifying the pyrite and the quartz, so that the amount of severe crushing would be lessened and therefore the attrition of the flake be reduced to a minimum.

The lack of uniformity in the ore is a factor frequently overlooked. The concentration processes are very sensitive to any change in the character of the ore. "To a certain extent the problems encountered by each operator are unique, as slight differences in the mineralogical composition of the ore may compel operators in near-by mines to instal decidedly different types of machinery. In some instances, even in the same mine, the ore may vary sufficiently as the work is extended to make it necessary to alter the concentration process. The fact that those companies that have a rather uniform kind of ore in their mines are also frequently making changes in the methods of concentration, is further evidence of unsolved problems."¹

Most of the bedded deposits carry pyrite; the normal schists about 4 per cent, the Bly ores 7 per cent, and the Rowland-International-Sacandaga class 11 per cent by weight, while the Rock Pond ore is exceedingly rich in this sulphide, which runs from 15 to 40 per cent of the rock. As the rock is crushed for the graphite content, it would seem that perhaps this could be saved without adding materially to the milling cost. Pyrite might be a profitable by-product.

The amount of graphite is perhaps the first matter that interests the average graphite man. While this is of vital importance, it is not the only factor. The writer has not taken the time to make chemical analyses of the different ores collected, the microscope enabling him to obtain a far better opinion of values. The example of the "rich" Rowland ore, illustrates this point. In St Lawrence county, where metamorphism has not been so severe, the crystallization of the carbon content of the old sediments to graphite has not proceeded so completely, and the percentage of "amorphous"

¹ Miller, B. L., *Topo. and Geol. Surv. of Pa. Rep't 6*, p. 82.

(really micro-crystalline) graphite is much higher.¹ Certain deposits of this kind will assay 20 per cent of carbon, but the value of such an ore is relatively low. In fact, successful graphite milling is one of the few industries that has a very close relation to the geology of the ore. Lack of knowledge of the geologic conditions then has been a considerable factor in the many failures.

"There is far more secrecy among graphite producers in regard to the milling methods employed than in almost any other kind of ore separation and (some) companies . . . refuse to admit visitors to their mills. The extremely small probability of one company profiting by the experience of another and thereby injuring its market through increased competition would seem to indicate the uselessness of secrecy employed by many graphite companies. On the contrary, there is little doubt but that the increased prosperity of one company would have a beneficial effect on all the others in the district, at least until the production increased far beyond its present proportions, and the problems of concentration might be more speedily solved under the plan of cooperation and mutual assistance."²

¹ Newland, D. H., N. Y. State Mus. Bul. 120, p. 30.

² Miller, B. L., Topo. and Geol. Surv. of Pa. Rep't 6, p. 82.

COMMERCIAL STATUS

Bastin says that "Today there are more abandoned mines and mills in the United States than the number in operation . . . In the number of times some of these properties have changed hands in the course of a few years, there is a record of misrepresentation and disappointment that can hardly be equaled in any other branch of mining, and many properties have been notoriously associated with stock manipulators of doubtful character."

Newland reports that "The amount of capital expended in the erection of new milling plants and mine equipment during the past five years aggregates several hundred thousand dollars, and in many cases there has been little or no return for the outlay."¹

Of the thirty-seven graphite properties here listed, only three are in full operation, two of which are recently organized companies.

The causes of these failures are many and varied. Some of them have already been pointed out. The mining and milling of graphite is a highly technical matter; it is not an easy and quick road to wealth. It demands a knowledge of the nature of the ore, its tenor, the geological condition of the surrounding area, the precise location of faults, folds, pinches, and swells, how the ore will crush, the size and quality of the flake, of the best, the average run and the poorest ore, how much mica is present etc. It is necessary to know the possible resources and secure a mill equipment to correspond. There are a great many factors that must be considered before actual operations are undertaken.

The writer has been greatly impressed by the lack of diamond drilling in most of the graphite districts. Only two properties have used this valuable method of securing data, and even then full benefit from the cores has not been obtained. The drill records are usually made by laymen in geology, and only the portions that are composed of ore are saved. Some records, furnished to the writer, were fairly intelligible and proved of value in detail mapping, while others were so ambiguous as to be more confusing than helpful. When a core is recovered, every inch of it should be saved! In one case a geologist who had the stratigraphy of the district in mind could have furnished the owners a fairly complete description of the conditions that would be found underground. All this information has been lost with the loss of the cores. Sometimes where diamond drilling has been done it has been so planned that little or no returns

¹Newland, D. H., N. Y. State Mus. Bul. 120, p. 30.

could have been expected. One company sank a drill in a mass of the Algomian gabbro in search of ore, when a geologist could have saved them time and money. The writer has no personal axe to grind, but he wishes to call attention to the fact that consulting mining geologists are available, whose services would cost less and save the expensive mistakes of present methods.

Besides the more technical problems, there are the financial questions. The writer believes that Bartley's recent article¹ has a great deal of truth in it that is of value to us and hence he has abstracted certain portions of Bartley's paper. Bartley believes that graphite companies who simply mine and mill the ore, selling the concentrates or finished products to graphite manufacturers are usually operating on a narrow margin of profit. This usual practice has been one of the causes of the unstable conditions and the fluctuations in the industry generally prevailing in this country. Bartley thus comes to the conclusion that the methods which have proved detrimental must be done away with and that "the successful American graphite miner must be to a certain degree a manufacturer." To illustrate this point he assumes that the finished product of the average plant is as follows:

- 1 Flake, 90-95 per cent carbon
- 2 Flake, 68-72 per cent carbon
- 3 Flake, 24-28 per cent carbon
- 4 Flake, 8-12 per cent carbon

"The first has a ready demand, and the price is based on the price asked in the Ceylon market for similar grade. The price (before the war) was about 9-10 cents a pound. (It is used in crucible manufacturing, for lubricants, and for special electrical requirements.) There is less demand for the second grade and the price, naturally lower, running (in normal times) around 4-4½ cents. It is principally sold to manufacturers of graphite oils, graphite greases, stove polish, etc. The two lower grades are of little, if any, value to the miner, who often is glad to dispose of them at any price.

"Here to my mind is the secret in mining American graphite successfully. It costs just as much to mine and refine the lower grades as for the higher. The next thing to consider is the average yield of graphite the mine will deliver, how this yield when finished will divide up into the four grades, etc.

¹ Bartley, Jonathan, "Can Profits Be Made in American Graphite?" *Iron Age*, July 8, 1915, p. 86-87.

(The experiences of Kemp, Bartley, Bastin and the writer suggest that the average percentage of graphite in the average ore is about 4 to 5. This means that from every net ton of mined rock only 80 to 100 pounds of concentrates will be produced).

"I believe that the following statements can be depended on as a fair average (before the war):

Every 100 pounds of concentrate will yield:

	<i>Market price</i>
35 per cent of first grade at 10 cents.....	\$3.50
20 per cent of second grade at 5 cents.....	1.00
15 per cent of third grade at 2 cents.....	.30
30 per cent of fourth grade at 1 cent.....	.30
	\$5.10 or 5 cents a pound

(One net ton is thus worth \$100.) "To produce the same in concentrates at a cost of 4 cents a pound means \$80; the cost of refining can be placed at \$4 a ton, making a total cost of \$84, thus giving a net profit of \$16 a ton. *No man can run a graphite mine on this margin of profit.*

[Then he must manufacture graphite products as well as produce.] "Why sell [the first grade] for 10 cents a pound when [it is possible to] get from 14 to 16 cents for it [as a manufactured product] with very little added cost? A very large percentage of this is sold for lubricating purposes, put up in tin cans . . . With a steam-jacketed kettle and a couple of mixers you are equipped to convert the second grade into graphite oils and greases [securing 15 to 25 cents a pound instead of 5 cents]. With paint grinding mills and mixers you are fixed to make use of the third grade, and realize at least 5 cents a pound. By adding soapstone" etc., to the fourth grade you can get 3 cents a pound for it as foundry facings, instead of 1 cent. It is a difficult matter even to estimate the cost of the machines needed in manufacturing such products. Bartley's opinion is that it would be in the neighborhood of \$6000 "to handle the output of a 75-ton mine." It seems to the writer that that is an exceedingly low figure, and that the probable cost would be much higher.

The writer has gathered the impression that one of the causes of the comparatively low price obtainable for concentrates is due to the fact that the producers of graphite articles "play one mine against another" and thereby keep the market price at such a low point that the margin of profit is dangerously small. During

the period of the war the price of the highest grade has risen, while the market value of the lowest grade has fallen. The present prices will not continue after the war.

The present prices average¹: No. 1 flake, 88 per cent of graphitic carbon, 12½ to 15 cents a pound; No. 2 flake, 82 per cent carbon, 9 to 12 cents; dust, 40 per cent carbon, ¾ cents.

THE PROSPECT FOR FUTURE PRODUCTION

Ore reserves are always mere guesses based upon probabilities. Nevertheless the writer offers the following estimates.

The American Graphite Company has undeveloped lands, but it is not possible at the present time to estimate the tonnage of its reserves. In the matter of probable reserves the following properties can be regarded as commercially important: the Faxon property, Hooper Brothers', the Flake Graphite Company and the Graphite Products Corporation, which have a collective reserve estimated to be in the neighborhood of 10,000,000 to 13,000,000 tons of graphite schist, half of which is readily available. This is not counting the Bly property, which is probably out of the running, for the present at least, until a concentration process can be devised to handle the mica.

In conclusion, the successful graphite miner will be one who has an extensive deposit of the bedded schist of uniform grade, measurably free from mica, without geological complexities, who operates in a large way and manufactures a good share of his own products.

ARTIFICIAL GRAPHITE

Graphite made in the electric furnace or as a by-product of the blast furnace has been regarded in lay circles as forecasting the doom of the mining of graphite. This is true to only a very small extent, and does not affect the Adirondack deposits of *flake* graphite. The electric furnace product is manufactured from coal and is amorphous. Its use is chiefly confined to the manufacture of dry batteries and electrodes. The carbon that accumulates in the washing tanks of illuminating gas companies is likewise put to similar uses. This amorphous carbon is not usable in the manufacture of crucibles and certain graphitic greases.

The flake graphite in slags is highly charged with oxides of iron, which reduce its refractibility to such an extent as to render it

¹ Newland, D. H., Eng. and Min. Jour., Jan. 19, 1918, p. 151.

useless. Furthermore the flakes are usually thinner than the natural flake. Nature has produced a form of graphite that man, as yet, has not equaled.

THE ORIGIN OF GRAPHITE

The discussion of the origin of graphite is of commercial and of scientific interest. The important rôle that origin plays in "sizing up" a graphite property has been pointed out in the preceding pages, and it does not need to be repeated here.

The origin of the mineral has been a favorite topic for many pens, and almost as many theories have been advanced as there are writers on the subject. The causes of these antagonistic views are varied. In essence it has been the conflict between the organic and the inorganic theories. Some would claim that all deposits have had an organic origin, while, on the other hand, the other extreme is maintained.

The writer is in full accord with Kemp, Bastin, B. L. Miller and Winchell, that graphite has been formed by *both* processes, acting entirely independently and sometimes in conjunction.

The attempt to arrive at the origin of the graphite in the Adirondacks is made difficult by the early views that still persist. Such statements that: "The Dixon . . . Company has in its mine near Graphite a fissure vein of small thickness but of great length and depth, cutting through gneiss,"¹ or what Cirkel reports as Kemp's description of Lead hill "as true fissure veins,"² and that the ore at the Flake Graphite Company is a metamorphosed dike,³ obscures rather than clarifies our problem.

The organic type of graphite. Bastin⁴ presents an imposing array of arguments to support the contention that the "Dixon" schist as shown at the mining village of Graphite is of sedimentary origin. He summarized them as follows: "(1) in the highly quartzose, nonfeldspathic character of most of the graphitic rock; (2) in the evenly and highly garnetiferous character of much of the wall rock [the Hague gneiss]; (3) in the persistence of the graphitic schists and associated garnetiferous gneisses with fairly uniform trend, width and character for considerable distances; (4) in the presence locally of interbedded masses of crystalline

¹ Ingalls, W. R., *The Mineral Industry*, 1908, 17:493.

² Cirkel, Fritz, "Graphite," *Can. Dep't of Mines, Mines Br.* 1907, p. 56.

³ Nicholas, F. C., *Min. World*, Jan. 4, 1908, p. 18.

⁴ Bastin, E. S., "Origin of Certain Adirondack Graphite Deposits," (*Econ. Geol.* 5:134).

limestones [the Faxon limestone]; (5) in the fairly even dissemination of the graphite through the workable schist." He further supports these arguments by a chemical study of the schist.¹ All of this evidence can be summed up in a few words: The Dixon schist is a stratigraphic unit in a sedimentary series. Having settled to his satisfaction that the schist is sedimentary, Bastin concludes, and the writer feels quite correctly, that this graphite is organic in origin.

But the graphite, as such, was not present in the original clastic sediments when they were deposited in the Grenville sea. Graphite in unmetamorphosed sediments is known² but such occurrences are rare and without much question the graphite has been derived from preexisting metamorphic rocks which have suffered disintegration. We can dismiss this factor as unimportant in the formation of the Dixon schist.

Walcott³ has suggested that the Dixon is a metamorphosed coal seam. There are several serious objections to such an interpretation. (1) The metamorphism of a coal bed usually gives a true amorphous or microcrystalline form of carbon; (2) from our present knowledge of coal it would seem improbable that a sufficiently developed form of life had appeared in Grenville time to have furnished coal.

Kemp's view is that the original rock was a bituminous shale. If we use the term shale loosely, chiefly as signifying a structure, then there is no difficulty in accepting this view, but if an argillaceous sediment is implied then this can be criticized on the ground that the Dixon schist is not a metashale but a metasandstone. Bastin maintains that "it seems most probable that the deposits represent carbonaceous sandstones, locally clayey, interbedded with only slightly carbonaceous impure sandstones and with small amounts of limestone, all of which have been completely recrystallized with the development of a schistose structure and the conversion of the original carbonaceous material into graphite through the usual processes of dynamic metamorphism."⁴ There is some objection to Bastin's term "carbonaceous." True carbonaceous matter in black muds seems to have been derived from ligneous material. Plants

¹ See Bastin, E. S., "Chemical Composition as a Criterion in Identifying Metamorphosed Sediments." *Jour. Geol.*, 17:445.

² In Cambrian sandstone, as reported by E. T. Wherry, *Econ. Geol.*, 7:764, and in Triassic Sandstone of Massachusetts, Emerson, *Mon.* XXIX, U. S. G. S., p. 365.

³ Walcott, C. W., *Bul. Geol. Soc. Am.*, 10:227; U. S. G. S. *Bul.* 86, p. 398.

⁴ Bastin, E. S., *Econ. Geol.*, 5:134, et seq.

containing lignum, that is, vascular plants, apparently do not appear until the Lower Devonian and hence algae¹ are called upon to supply the carbon. On the decay of such plants an odoriferous thick oil ("sapropelic" matter) results that can be regarded as akin to bitumin; hence the writer prefers the term "bituminous sandstone." The habitat of these algae seems to have been shallow water near the shore. This view is strengthened by the gradual disappearance of the Faxon limestone to the east and its replacement by metaarkoses and metagraywackes, indicating that the shore of the Grenville sea at Dixon-Faxon time was to the east.

All the specimens of the graphite schists (all types) studied revealed considerable amounts of pyrite. A large proportion of this has been introduced; two distinct periods are clearly recognizable, especially in case of the Rock Pond ores where an excessive amount permits easy observation. A small amount, however, appears to have been an original constituent in the argillaceous sandstones, or that the iron content was in the form of chloritic minerals. During metamorphism "much of the iron is reduced to the ferrous condition . . . and it may . . . combine with sulphur, which is often present under these conditions, to form pyrite. The presence of 'carbonaceous matter' favors this reduction, as shown by the common association of . . . sulphides with graphitic shales."² Smyth³ points out the close genetic relations of pyrite and graphite. That graphite, as such, or as organic carbon, having the property of precipitating the pyrite has been pointed out by Von Cotta⁴ and Jenny.⁵ Smyth⁶ says: "Thus, for the graphite, a history somewhat similar to that of the pyrite is indicated, but with the difference that most of the former is thought to be carbon that was original in the sediments, which has undergone some concentration and may have received minor additions from magmatic sources, [see later] while, in the case of the pyrite, the relative importance of these sources is reversed." Thus the evidence furnished by the pyrite would add support to the contention that the carbon was present in the sediments as an original constituent.

¹ White, David, *Econ. Geol.*, 3:298; Osborn, H. F., "The Origin and the Evolution of Life," 1917, p. 50, fig. 5.

² Leith, C. K., & Mead, W. J. "Metamorphic Geology," 1915, p. 104-5.

³ Smyth, C. H., jr., "Origin of Certain Adirondack Pyrite Deposits," 65th Ann. Rep't, N. Y. State Mus. 1911, 1: 174 et seq.

⁴ Von Cotta, "Treatise on Ore Deposits," *Eng. Trans.* p. 46-47.

⁵ Jenny, W. P., "The Chemistry of Ore Deposition," *Trans. Am. Inst. Min. Eng.*, 1903, 33:455-57.

⁶ Ibid. (see p. 182) footnote.

The change of organic carbon to crystalline graphite has been affected by the heat and pressure, accompanying mountain-making stresses, or static metamorphism, causing the volatilization of hydrogen and nitrogen, and the dehydration of the residue, followed by the recrystallization of amorphous carbon to graphite.¹

The sedimentary limestone type. When discussing the northern area with its characteristic type of graphite, emphasis was purposely laid upon the contact type. While the majority of the prospects and mines are situated at contact zones, some of the limestone appears to be graphitic without any necessary connection with igneous rocks. The limestone, for example, throughout the Paradox Lake quadrangle was frequently observed to be slightly graphitic. The most plausible origin for the graphite in this rock is that it is organic. It may be that the history of the carbon here has been very similar, if not identical with the formation of the Dixon schist. It is a striking thing that as we pass into the interior of the Adirondack highland the limestones become barren of graphite. Whether this is due to the action of igneous rocks culminating in the great anorthosite body or due to the fact that we are moving away from the old Grenville shore into areas where deep-water conditions prevailed, is, of course, unknown.

THE INORGANIC TYPE OF GRAPHITE

The contact form. Graphite occurs at contact zones between an igneous rock and a sedimentary one, usually in contact rocks rich in pyroxenes, and in the margins of the eruptive rock. The statement that graphite occurs in pegmatites is probably true *per se*, but it seems to the writer to be somewhat misleading; for it is confined to the margin along the line of contact. Apparently the country rock was a necessary reagent in the formation of the graphite. Several specimens collected on Lead hill were first taken to be limestone with graphite. The trial with a knife blade proved that the white material was too hard for calcite, hence it was called pegmatite material. A thin section showed it was white pyroxene; hence it was a contact rock, not a pegmatite.

There are two views in regard to the origin of the contact form of graphite: (1) that the carbon, in some form, was an original constituent of igneous magmas, or (2) that the igneous rock in its

¹ See Hatch, F. H. & Rastall, R. H., "Petrology of the Sedimentary Rocks," London, 1913, p. 293.

ascension through graphitic sediments picked it up and deposited it on cooling at the margins of its mass.

Winchell¹ states that "graphite is practically insoluble in silicates at ordinary temperatures of magmas; it is upon this fact that its value as a refractory material partly depends. How, then, can the occurrence of graphite as a constituent of igneous rocks . . . be explained?" The temperature of liquefaction and vaporization of graphite is in the neighborhood of 3000° Centigrade at normal pressures. The effect of increased pressure in raising the melting point is so small that we may neglect this factor.² "Therefore the suggestion sometimes made that sublimation from carbon vapor [is responsible] seems highly improbable."³ It seems equally clear that carbon could not be in silicate solutions as a solid in an undissolved form or in true solution.

Volatile hydrocarbons are then offered as a source of graphite.⁴ That such gases do occur as constituents of igneous rocks, has long been recognized.⁵ Winchell has ably discussed the probabilities and points out that "it seems improbable that they are the source of graphite deposits, for several reasons. First, in the presence of water they will apparently be wholly transformed into carbon monoxide and hydrogen at 700° to 800° C. Second, in the absence of water the decomposition of hydrocarbons occurs (only) at high temperatures . . . ; any graphite that resulted from such a process should be formed in the hottest part of the intrusive magma rather than in the much cooler (margins) . . . where the graphite is actually found; and . . . no reaction is known for the decomposition of hydrocarbons below 500° C."

In a similar way Winchell disposes of the theory that the rôle played by carbides is responsible for the formation of graphite.

The most plausible theory is that the ultimate source is either carbon dioxide or carbon monoxide. Examination of the pegmatites from a great many of the contact deposits of the northern area shows microscopic gas bubbles of the oxides of carbon in great abundance. Lincoln,⁶ Chamberlain⁷ and Salisbury⁸ point out that

¹ Winchell, A. N., "A theory for the Origin of Graphite," *Econ. Geol.* 1911, 6:222.

² Harker, Alfred, "The Natural History of Igneous Rocks," 1909, p. 163.

³ Winchell, *ibid.*

⁴ See references given by Winchell.

⁵ Lincoln, F. C., *Econ. Geol.* 1907, 2:257; Chamberlain, R. T., "Gases in Rocks," *Carnegie Inst. Pub.* 106.

⁶ Lincoln, F. C., *Econ. Geol.*, 2:258.

⁷ Chamberlain, T. C. & Salisbury, R. D., "Geology," 1:618, 619.

⁸ Chamberlain, T. C., *Carnegie Inst. Pub.* 106.

the oxides of carbon certainly exist in magmas as they are important constituents of volcanic emanations. The experiments of Boudouard¹ with the system CO—CO₂ in equilibrium, show that on cooling from 1000° to 500° C. at normal pressures CO breaks up in CO₂ and "lamp black."



This form of carbon may be converted into graphite by the application of pressures and heat, as is illustrated by its presence in gray cast iron.

Bastin² sought to arrive at the temperature at which graphite of the contact type was formed. He examined a suite of specimens from Lead hill, and found that the "quartz was penetrated in a most irregular manner by flakes of graphite oriented in all directions and inclosed numerous crystals of augite. There can be no doubt that the three minerals crystallized contemporaneously." The quartz was examined in the light of the modifications that quartz experiences when subject to thermal changes;³ and was found to be in the alpha condition. This indicates beyond reasonable doubt that the quartz, graphite and augite crystallized below the inversion temperature of quartz, which is 575° C. This temperature is in accord with the experiments of Boudouard and the conclusions reached by Winchell.

Weinschenk⁴ believes that any kind of igneous rock can, if the physical conditions obtain, produce graphite upon contact with any kind of calcareous sediment. The examination of all the contact deposits of the Adirondack strongly supports this view. The Fryatt workings on Lead hill, however, where the sediment is a good clean quartzite seem to question the necessity of limiting such action to calcareous rocks.

The vein type of graphite. The true fissure veins of Split rock, Lead hill and the Rowland property, as well as elsewhere, indicate that the graphite-forming period continued after the solidification of the pegmatitic-granite, syenite, gabbro or whatever particular series of igneous rock that carried the oxides of carbon. But the graphite is no less magmatic when it occurs in veins than the quartz with which it is associated. The quartz is a hydrothermal product.

¹ Ann. Chim. Phys., 1910, 29:5

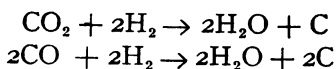
² Bastin, E. S., Econ. Geol., 5:134.

³ Wright, F. E. & Larson, "Quartz as a Geologic Thermometer," Amer. Jour. Sci., 1909, 28:423-77.

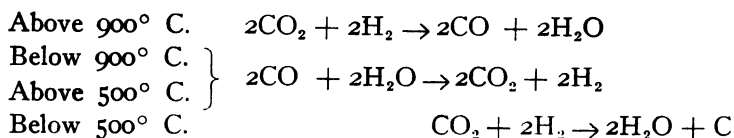
See Fenner, C. N., Amer. Jour. Sci. iv, 36:331-81.

⁴ Weinschenk, E., "Memoire sur l'histoire du Graphite" Compt. Rend. VIII Congr. Geol. Internat. 1900, p. 447. Zur Kenntniss der Graphitlagerstätten.

Reasoning based upon the work of H. Dixon¹ indicates that the following reactions are reversible:



But the intermediate steps appear to be:



This goes to show that the oxides of carbon (gases) in the presence of gaseous water react to form graphite. Much of this water is probably magmatic, while some of it may be derived from the sediments. Available analyses of such rocks give from 1 to 2 per cent of water. This may partly explain the occurrence of graphite at the margins of pegmatites; the heat of the intrusive releasing it from the sediments and acting as one of the reagents. In a similar manner the CO_2 from limestones (CaCO_3) may have been liberated and thus there is furnished another reagent for the process.

Applying the theories outlined above it is reasonable to expect that "any magma which contains sufficient water, upon coming in contact with bituminous (sediments) may be expected to convert all that portion of the carbon which is heated above . . . 600° C. to the oxide state. The resulting gases are soluble in water and silicate melts. When this solution cools below 600° C. graphite may be expected to crystallize out . . ."² If this explanation of the origin of graphite is correct, then certain contact deposits may have a complex origin; the carbon being derived from organic remains in sediments was picked up by the intrusive (as oxides) and redeposited. Such a process may possibly be the one responsible for the contact and vein types on Lead hill. This is suggested upon the basis that in the Barrett Construction Company's abandoned spar quarry, on the eastern slopes of Lead hill, there is shown the Hague gneiss enveloped by the same pegmatitic-granite mass that forms Lead hill. If the stratigraphy of the Grenville, as here developed,

¹ Dixon, H., Jour. Chem. Soc., 1886, 49: 94.

² Winchell, loc. cit.

can be relied upon, it is safe to infer that a bed of the Dixon schist should have underlain the hill before the injection of the igneous rock. Thus the pegmatite may have derived the graphite from the Dixon and deposited the graphite upon contact with the higher lying beds such as the amphibolite in the Young Lion pit, which may be the Beech Mountain rock, etc.

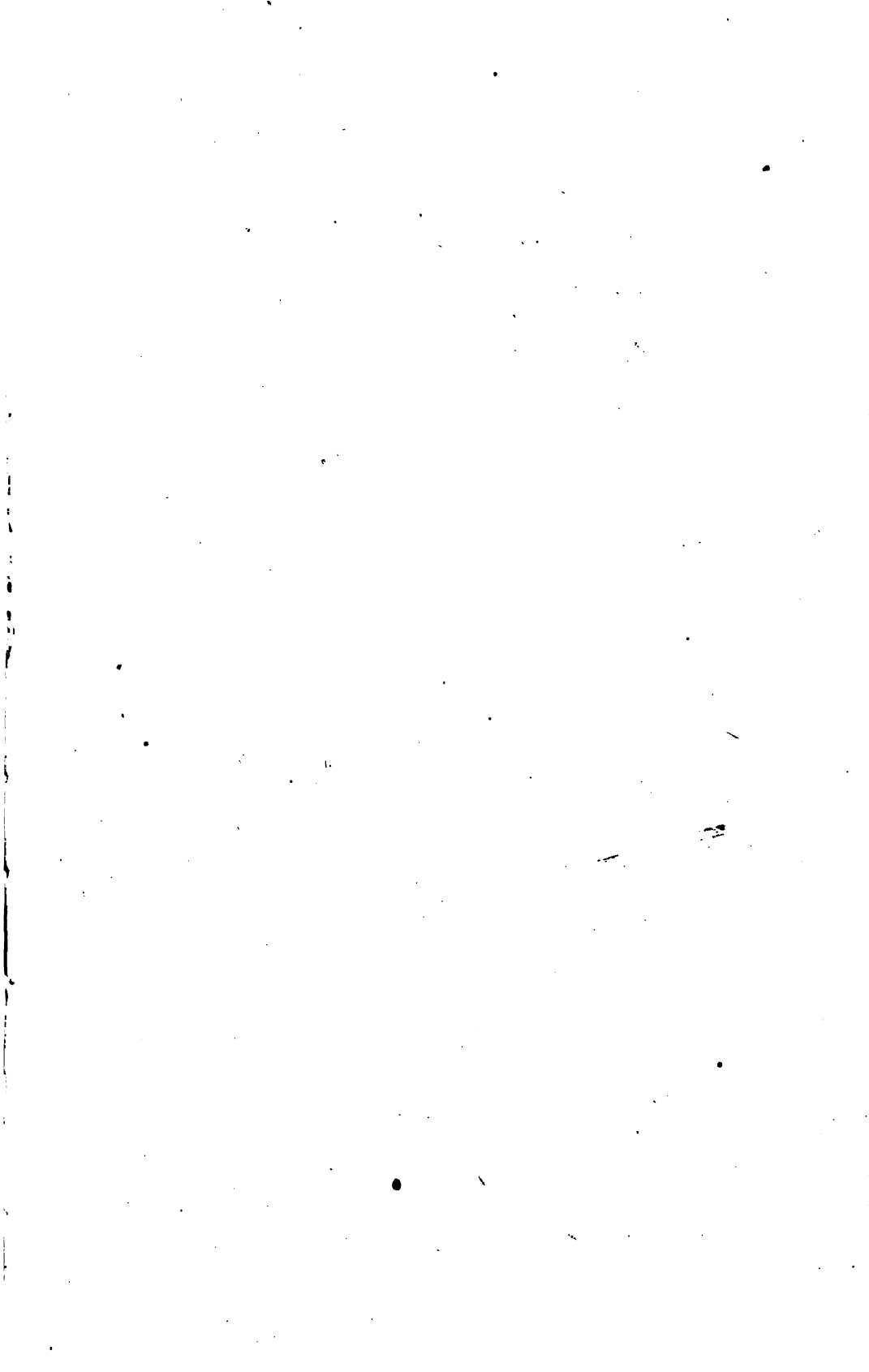
The slightly contact metamorphosed type. The enriched ores of the International, Rowland and Sacandaga properties probably were developed by a mild form of this absorption and redeposition action of the thermal waters upon the graphite of the original Dixon schist, causing a concentration-enrichment effect.

Summary. Thus it is concluded that the graphite in the Adirondacks has been formed by several distinct and rather complex processes. The organic origin is proposed to explain the Dixon, Bear Pond schists, and the Rock Pond "arkosite." The inorganic theory is regarded as the most plausible to explain the contact and vein deposits, while a combination of the two is held to account for the International-Rowland-Sacandaga type and perhaps some others.

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